HEAVIER THAN AIR

The Enabling Role of Bureaucracy in Cross-Expertise Collaboration

by

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ABSTRACT

This thesis explores the enabling role of bureaucracy in cross-expertise collaboration. Based on 13 months of ethnographic fieldwork in the engineering unit of an aeronautical company, and focusing on a myriad of different specialists involved in the company's product development, I show that bureaucracy (i.e., understood as the rationalization of work) provides the infrastructure for the collaborative work of various experts. More specifically, through eight embedded cases, I examine how bureaucracy shapes cross-domain meetings, knowledge exchanges, and the work of intermediaries, making these dynamics more unambiguous, calculable, reliable, and precise. By reducing uncertainty, bureaucracy enables specialists to engage in focused and productive exchanges and interactions. I identify three conditions that underpin the positive impact of bureaucracy in this context and present four of its enabling roles in cross-expertise collaboration. Namely, these are: clarifying responsibilities, interconnections, and complex processes; promoting impartial relations and reducing tensions; ensuring participation in systemic matters; and streamlining integration. Overall, the thesis takes bureaucracy out of the shadows in our understanding of collaboration processes. It also contributes to studies on expertise coordination by highlighting that in highly-interdependent work situations formal organizational elements co-exist — and complement — emergent integration/coordination mechanisms. The thesis also contributes to the general organizational scholarship by putting forward a more appropriate understanding of bureaucracy in contemporary organizations which underscores its multifaceted nature. The work also has implications for the practitioner-oriented literature on collaboration, emphasizing the value of functional structures and formalization when most authors sing the praises of team-based arrangements and 'organic' structures.

Para meus avós e avôs — Aloísia, Caterina, Severino,
e Eber — que desejaram conhecimento e educação,
mas nem sempre puderam alcançar esses objetivos.
Essa dissertação é dedicada a vocês.

To my grandmothers and grandfathers — Aloísia, Caterina,
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education, but could not always attain it.
This thesis is dedicated to you.

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DECLARATION

This thesis is submitted to the University of Warwick in support of my application for the degree of Doctor of Philosophy. It has been composed by myself and has not been submitted in any previous application for any degree.

The work presented (including data generated and data analysis) was carried out by the author.

No parts of this thesis have been published.

If things are going well, we talk of cooperation
if they are going badly … we speak of
"this goddamned bureaucracy"
(Charles Perrow, 1986)

CHAPTER 1

INTRODUCTION

Carl Hammoud – The Revision

Preamble: Missing Bureaucracy in Cross-Expertise Collaboration

Albert joined PlaneCo a decade ago. He is a product development engineer working on a new commercial aircraft. Today he planned to work on some engineering analyses. However, these depend upon information from another group that is late. So he asks a senior colleague to help him work out when it is likely to be delivered. Later he calls an expert from another area to request some design data. After some back and forth, they agree on a deadline and Albert emails a fellow in the product management team about it.
[…]
Albert checks his to-do list and realizes he owes some time-sensitive information about an aircraft part to a drafter who requested it weeks ago. He knows that sending it late would compromise the release of technical drawings to manufacturing, thus upsetting the production schedule (and putting him in an uncomfortable position).
[…]
A member of the product management team calls Albert. He says that a technical solution proposed by some peers may impact the system overseen by his group. Thus, they ought to do some studies and report whether any significant alteration is likely to be needed. Albert agrees to share their position on the matter within a week so he can incorporate it into his presentation to the chief engineer.
[…]
A colleague from his group then surprises Albert, asking him to step in for him in a cross-domain meeting. He is a bit reticent at first, but his colleague insists: he was summoned last minute to go to a conference call with suppliers and someone from the group needs to attend the other meeting. Albert agrees. He goes to the gathering where he finds representatives from most of the engineering unit areas and signs an attendance list on behalf of his colleague.
[…]
Albert and colleagues attend a progress review session led by a senior member of the group. While checking advancements and assigning new activities to each one of them, the leading worker stresses that some deliverables are priorities — due to interdependencies or because they had been highlighted as time-sensitive.

The vignette above illustrates the everyday of Albert, a generic product engineer. He interacts with a multitude of specialists from different domains, requests and provides information from/to them, participates in joint problem-solving sessions, integrates contributions into technical discussions, adjusts activities according to interdependencies, and overall aims to work in alignment with peers. All this takes place in the engineering unit of PlaneCo, a major aeronautical company which designs, manufactures and supports aircrafts flying all across the world.

PlaneCo is a pseudonym, and Albert is a composite narrative (a placeholder for a collection of situations which a number of individuals in the company face). Nevertheless, the cross-expertise collaboration he is involved in is very much real. I witnessed it first-hand during thirteen months of fieldwork in PlaneCo headquarters reading internal publications, interviewing and shadowing employees, attending meetings, and informally chatting with a whole range of people at their workstations, during lunch breaks, and while walking through the corridors

At first, dynamics such as the ones described in the vignette above appeared to be all about common ground, inter-personal ties, meetings, shared meanings, liaison roles, mutual adjustment, and similar elements which have been well-studied by cross-expertise collaboration scholars (Barley, W. 2015, Bechky 2003, Ben-Menahem et al. 2016, Bruns 2013, Carlile 2002, DiBenigno and Kellogg 2014, Kellogg et al. 2006, Kaplan et al. 2016, Nicolini et al. 2012). However, as time passed — and my research advanced — I realized there was more to the story. Despite being absent from the pages of the literature, bureaucracy was very much present in the field, a silent-yet-effective infrastructure underpinning collaboration processes. In PlaneCo, there are procedures and control mechanisms regulating the involvement of experts in project gatherings; formal channels ordering information exchanges; and 'offices' in the (lateral) hierarchy occupied by intermediaries adjusting and integrating the activities of various groups.

Unraveling how bureaucracy intermeshes with and enables cross-expertise collaboration is the goal of the present thesis — one that I capture with the aeronautical notion of "heavier-than-air." This expression is synonymous to aircrafts and refers to the early idea that only objects lighter-than-air could fly (e.g., balloons). An idea which was eventually proved wrong. As we know today, flying is less about 'lightness' and more about the design of aircraft. Similarly, cross-expertise collaboration is usually perceived very much as a structureless endeavor and bureaucracy is taken to be a 'heavy' factor that brings it down (Chompalov et al. 2002). However, I will show that as much as something intangible as flying can be accomplished by "heavier-than-air" machines, a "heavier-than-air" bureaucracy can actually be what makes collaborative dynamics possible. In the remainder of this chapter, I outline how I will go about accomplishing this mission.

The Forgotten Infrastructure of Cross-Expertise Collaboration

Cross-expertise collaboration[1] denotes the challenges individuals from distinct knowledge domains face when working together. This is a central theme in organizational and management scholarship since organizations are by definition machines which achieve goals through the work of a variety of individuals (Scott 2003: 26). Thus, experts of all sorts find themselves having to integrate their activities and outputs with each other (Lawrence & Lorsch, 1967; Mintzberg, 1993; Okhuysen & Bechky, 2009). Cross-expertise collaboration also represents the foundation of a number of organizational processes, such as innovation, change, and strategy-making (Aram and Morgan, 1976, Gardner 2016, Heckscher 2007, Adler et al. 2008).

In this thesis, I am interested in understanding how cross-expertise collaboration is accomplished within formal organizations. I consider 'collaboration' as a broad term which identifies the activities of workers involved in interdependent accomplishments; it includes, among others, practices like interacting, sharing information, integrating contributions, jointly making sense of problems, adjusting activities, and boundary spanning (I explore all of these in the present thesis). Similarly, I use the term 'expertise' in a general manner in reference to the specific know-how and skills an individual possess (all these definitions are further detailed in the next chapter).

The scholarship exploring the collaborative work of distinct experts is extensive. It covers, for example, studies of the joint development of complex technological products in scientific centers (Nicolini et al. 2012, Tuertscher et al. 2014), multidisciplinary decision-making in hospitals (Oborn and Dawson 2010, Liberati et al. 2016), cross-boundary problem-solving in manufacturing firms (Hsiao et al. 2011, Carlile 2002), collective brainstorming and knowledge integration in professional firms (Majchrzak et al. 2012, Kellogg et al. 2006), and expertise coordination in high-tech settings (Faraj and Sproull 2000).

A central discussion in this literature is given by how experts manage to work together despite differences in meanings, interests, tools and similar dimensions which

[1] To avoid repetition, throughout the thesis, I use expressions equivalent to cross-expertise collaboration, such as "work across expertise domains," omitting the exact word collaboration. For the same reason, I employ synonyms for expertise (e.g., knowledge) and experts (e.g., specialists).

may easily lead to miscommunication, conflicts, and even breakdowns (DiBenigno and Kellogg 2014, Mengis 2007, Faraj and Xiao 2006, Carlile 2002). Many authors have explored the conditions and mechanisms aiding workers to understand each other (Bechky 2003), to handle co-dependencies (Bruns 2013), to synchronize activities (Ben-Menahem et al. 2016), or more basically to make them willing to help each other out (DiBenigno and Kellogg 2014, Hansen 2013).

The most classic stream of studies in this scholarship are perhaps the ones focusing on boundary objects and boundary spanners. For example, authors show how boundary objects make professionals aware of differences and interdependences, thus enabling them to conciliate distinct interests and understandings (Bechky 2003, Carlile 2002, Nicolini et al. 2012). Similarly, students of boundary-spanning have documented how intermediaries connect experts, by dissolving local resistances and mobilizing resources to make collaborative relations possible (Kaplan et al. 2016, Hsiao et al. 2011, Levina and Vaast 2005).

What is left in the background in these accounts — and in the overall scholarship in the field — is bureaucracy. More specifically, by that I refer to whether collaboration dynamics exist in themselves or whether they are the consequences of (and intertwined with) the rationalization of work.[2] Studies show experts interacting with each other and facing occasional problems while apparently untouched by procedures, standardizations, or formal hierarchies. However, we know that bureaucratic structures are routinely frequent in organizations, be them research labs, manufacturing companies, or in professional firms.

For example, the amount of time/resources which experts have to visualize differences and to build common ground may depend on the formal processes taking place (cf. Bechky 2003, Kellogg et al. 2006, Tuertscher et al. 2014); specialists may have to refer to internal policies when problem-solving and discussing the contributions of each other (cf. Carlile 2002, Carlile and Rebentisch 2003, Majchrzak et al. 2012, Oborn and Dawson 2010); and liaising across groups and integrating them towards specific activities may be part of the job description of individuals occupying specific positions in the hierarchy (cf. Kaplan et al. 2016, Hsiao et al. 2011).

[2] Following Weber (1978), I define bureaucracy as a rationalization process. A more elaborate definition will be provided in the next chapter.

Nevertheless, the extant literature has thus far overlooked the role of bureaucratic mechanisms (the reasons for this are multiple and will be explored in detail in the next chapter). As Perrow aptly suggests, it seems that bureaucracy is only visible when it creates problems (Perrow 1986: 36). To be fair, the fact that bureaucracy is left in the background is not problematic in itself — social scientists must always highlight some aspects of reality while foreshadowing others to produce intelligible analyses. Yet, because we have ignored bureaucracy for so long, and because there is arguably an anti-bureaucracy bias in the organizational literature (see for a similar critique Adler 1999, Adler and Borys 1996), the current image of collaboration across expertise domains is one of specialists working in an ungoverned, or self-governed, manner in structureless settings (see Chompalov et al. 2002 for similar arguments).

Furthermore, bureaucracy is not only absent but also seen as antithetical to collaboration processes. Some scholars propose elements such as cross-functional teams, emergent coordination practices, and liaison roles as alternatives or even 'solutions' to bureaucracy (Elsbach and Bechky 2007, Fayard and Weeks 2011, Boutellier et al. 2008). However, the reality is that bureaucracy may co-exist and even be complementary to these elements. As my thesis will demonstrate, bureaucracy is very present in situations of complex knowledge flows, reciprocal interdependencies, and lateral interactions across specialist communities. And under certain conditions it represents the infrastructure for collaborative dynamics. In the next section, I clarify what I mean specifically when I talk about bureaucracy and my plan to showcase its role in cross-expertise collaboration.

An Appreciation of Bureaucracy

In this thesis, I am interested in bureaucracy as the rationalization of work (not in bureaucracy as a pre-set organizational form). Also, I understand rationalization as a process geared towards uncertainty reduction and based on formal rationalty as defined by Weber (Gajduschek 2003, Weber 1978). In other words, the aim is to make work practices and their interconnections less ambiguous, calculable, and precise (I further explain and justify these definitions in the next chapter).

Bureaucracy is currently not only neglected but also misrepresented in both the literature on cross-expertise collaboration and the general field of organization studies (see for a similar critique Gay 2005, 2000). To speak of it, is almost to speak of a tainted concept (Adler and Borys 1996). Decades ago, early authors, such as Gouldner, have already denounced the prejudice against bureaucracy and the tendency to understand it in a monolithic and reified manner without investigating how it actually operates in practice (Gouldner 1964, 1955, 1952). Thus, following Gouldner, my effort in this thesis is not only to bring bureaucracy to the fore but also to rescue it from the 'metaphysical pathos' entrapping it (Gouldner 1955).

To accomplish this, the thesis is constructed as an appreciative account of bureaucracy in cross-expertise collaboration — which is not different from the way studies praise the enabling roles of representations, intermediaries, trading zones and related paraphernalia in collaboration (e.g., Nicolini et al. 2012). I aim to counter-balance the propensity of organizational scholars to criticize bureaucracy by explicitly focusing on its enabling roles (I am, however, not interested in the impact of bureaucracy on employee welfare as Adler (2012) and other students of "enabling bureaucracy").

Consequently, some of the more hindering aspects of bureaucracy revealed by my fieldwork in PlaneCo are left in the background. This is a conscious choice in order to make the overall argument of the thesis sharper and more concise. Nevertheless, I recognize that bureaucracy is not a panacea for cross-expertise collaboration in PlaneCo or any other company. Thus, to qualify my analysis, and avoid the risks of turning this thesis into a hagiography, I will also examine the specific conditions that make the enabling roles of bureaucracy possible in the discussion chapter.

Thesis Scope and Research Questions

Thesis Scope

The thesis is based on an empirical investigation of a large aeronautical company (PlaneCo). However, it obviously does not account for all facets of this setting. Given the current focus on bureaucracy and cross-expertise collaboration, the empirical materials brought to bear stem from situations in which this intersection is most apparent. Thus, I am not very concerned with the bureaucratic processes observed during fieldwork that do not involve cross-expertise activities (e.g., design reviews which despite being very formal usually bring together experts from the same domain).

Furthermore, the thesis approaches the social phenomena in a cross-sectional manner: I examine how bureaucracy shapes ongoing collaboration processes while bracketing the reasons behind the enactment of bureaucracy in particular ways. Although I occasionally outline the origins of certain bureaucratic procedures to better situate some dynamics, a processual account about the emergence of bureaucracy goes beyond the scope of the present work.

Finally, I must note that I have strived for concision in the thesis mostly out of a concern for readability. Despite the large volume of materials collected during fieldwork, I chose to be 'economical' in the presentation of the data, trying to strike the balance between providing enough evidence without overloading the reader with details. Similarly, I decided to review and discuss only the relevant literature, instead of presenting a general historical panorama of the scholarship on cross-expertise collaboration and bureaucracy which I fear could dilute the argument of the thesis. Overall, I believe that the present document incorporates the core insights of my analytical work in a succinct manner.

Research Questions

The primary goal of the thesis is to bring bureaucracy to the fore in our understanding of cross-expertise collaboration and thus put forward a more balanced account of its relevance in such dynamics. The research questions guiding the process are the following:

- How does bureaucracy shape cross-expertise collaboration?
- What are the possible benefits that bureaucratic arrangements produce to work across expertise domains?

To address these questions, I start by focusing on the impact of bureaucracy in distinct cross-expertise collaboration processes. More specifically, I examine how bureaucracy shapes cross-domain meetings, knowledge exchanges, and the work of intermediaries in PlaneCo. Based on "embedded-cases" (e.g., different types of meetings), I highlight distinct facets of the impact of rationalization on collaborative work. In a second stage, I review the empirical materials as a whole in light of the relevant literature and I identify four enabling roles of bureaucracy for cross-expertise collaboration. Overall, the thesis shows that the importance of bureaucracy endures in contemporary knowledge work and puts forwards a more appropriate understanding of bureaucracy within organizational and management scholarship.

Thesis Outline

This first chapter provided a general overview of, and justification for the thesis, while presenting its contribution to the scholarship on cross-expertise collaboration. The next chapters are structured as follows. Chapter 2 reviews the pertinent literature, defines what I understand by cross-expertise collaboration and bureaucracy, and establishes the contribution scope of the thesis to scholarship. Following a general review of studies on work across expertise domains, I highlight how they overlook and neglect bureaucracy. I then explore the reasons behind such state of affairs and argue for the importance of studying bureaucracy in collaboration dynamics.

Chapter 3 introduces my ethnographic investigation. I justify the case selection and present details about my fieldwork in PlaneCo. Then, I explain how I sampled the embedded cases in which the intersection of cross-expertise collaboration and bureaucracy is visible, and the methods I employed to study them. I then detail how I analyzed the empirical material through an abductive process, mobilizing a particular understanding of bureaucracy in process, and outline the structure of the findings presented in the subsequent chapters. Finally, I also present some ethical considerations and some shortcomings of my research.

Chapter 4 is the first of four empirical chapters and describes the general characteristics of the company. It provides a brief introduction to PlaneCo, focusing on the structure, professionals, and ethos of the engineering unit. Subsequently, I outline the organization of the aeronautical product development in the company while highlighting how it generates some challenges for cross-expertise collaboration. I present the expertise structure in the engineering unit and discuss the extent to which collaboration among experts in PlaneCo is a requisite, a commitment, and a very regulated affair.

Chapter 5 opens the series on the link between cross-expertise dynamics and bureaucracy. It focuses on key cross-domain meetings in the product development of PlaneCo: technical, zonal analysis, and configuration control meetings. The former two bring together diverse specialists within the engineering unit while the latter one features experts from also other units (e.g., manufacturing). Bureaucracy is visible here in the requirements and protocols (sometimes embedded in routines and standards) upheld by appointed individuals, together with a strong dose of routinization. Overall, this chapter shows that bureaucracy makes systemic matters more tractable and governable, and the involvement — and alignment — of experts around them more reliable.

Chapter 6 deals with knowledge exchanges and the role of bureaucracy in them. It speaks to the dynamics which are linked to knowledge sharing and information processing. I explore three tools regulating, respectively, exchanges among engineering unit workers, between engineers and drafters, and among drafters. These cases show how bureaucracy formalizes the circulation of information thanks to the aid of tools which record the details about knowledge exchanges in writing. Among other consequences, the cases indicate that such formalization enhances the accountability of experts in their knowledge exchanges and makes the agreements established more easily enforceable.

Chapter 7 is the one that perhaps best illustrates the links between bureaucracy and cross-expertise collaboration. It concentrates on intermediaries, a generic term for liaisons, integrators, boundary spanners, and similar roles. Specifically, it presents the cases of ambassador and coordinators who facilitate relations among expert groups and govern interdependent processes, respectively. Bureaucracy is visible to the extent that these professionals occupy offices in a lateral hierarchy with specific responsibilities and resources. Thus, it provides official recognition for the work of these intermediaries and certainty about their existence in the company.

Chapter 8 considers the empirical materials as a whole and drills down the main insights in light of the relevant literature. I provide a general assessment of how bureaucracy reduces uncertainty in cross-expertise dynamics by proposing that it functions as an infrastructure for work across expertise domains. I then synthesize the benefits of bureaucracy for cross-expertise collaboration into four roles. Namely, clarifying responsibilities, interconnections, and complex processes; promoting impartial relations and reducing tensions; ensuring participation in systemic matters; and streamlining integration. Finally, I present the theoretical implications of the thesis for cross-expertise collaboration scholarship as well as for studies on expertise coordination, and for our general understanding of bureaucracy. I also offer some practical insights on the importance of bureaucracy in collaboration. The work concludes with some of its boundary conditions and future avenues for research.

CHAPTER 2

LITERATURE REVIEW

Carl Hammoud – Catalogue

Introduction: A Brief Overview of The Literature

This chapter explores the relevant literature on cross-expertise collaboration and the place of this thesis within this field. I start by outlining this large body of studies and I highlight the neglect towards bureaucracy by this scholarship. I then introduce a conceptualization of bureaucracy as the rationalization of work. After a critique of the narrow adherence to the Weberian ideal-type of many authors, I elaborate on how we may understand bureaucracy's role in cross-expertise work and lateral relations more generally. I then trace some causes for what I describe as the eclipse of bureaucracy and present how my thesis puts it back at the front and center of our understanding of collaborative work across expertise domains.

The Scholarship on Cross-Expertise Collaboration

Definition of Cross-Expertise Collaboration and Scope of the Review

In this thesis, I am concerned with the challenge that various types of knowledge pose to collaboration — instead of, for example, demographic or cultural differences (Majchrzak et al. 2012). I define cross-expertise collaboration as any interdependent activity that involves individuals with heterogeneous specializations. The literature on this phenomenon is vast and multifaceted: there is simply no unified body of studies (they span many sub-streams and approaches) nor any overarching keyword to describe the collaborative work of various specialists. Thus, I employ the term "cross-expertise collaboration" as an umbrella term for the notions of cross-boundary (Hsiao et al. 2011, Barley, W. 2015), cross-disciplinary (Nicolini et al. 2012, Bruns 2013), cross-functional (Jassawalla and Sashittal 2006, Carlile 2002), cross-occupational (DiBenigno and Kellogg 2014, Bechky 2003), inter-disciplinary (Kaplan et al. 2016), inter-professional (Liberati et al. 2016), and multi-disciplinary collaboration (Oborn and Dawson 2010, Cummings 2005). While these previous terms emphasize specialization resulting from different sources — such as the organizational structure (i.e., cross-functional) or professional education (i.e., inter-professional) — they all ultimately describe work that involves specialists from distinct knowledge domains.

I employ the term 'expertise' and related declinations (e.g., expert) as a neutral synonym for specialization. This does not presume any value judgment on the level of competence (Collins and Evans 2008) or the status in society of such individuals (Eyal 2013, Gorman, E. H. and Sandefur 2011). The use of the term "collaboration" follows a similar logic. I use it in reference to the general idea of working together and based on a metonymic strategy to indicate processes such as integration, coordination, cooperation, sharing, and boundary-spanning. Even though I am interested in interdependent work, I refrain from using the term 'coordination' because it also covers work arrangements without reciprocal interactions/exchanges (i.e., pooled coordination) which I take to be an essential element of collaboration (Bruns 2013). I also avoid the notion of 'cooperation' since it has an attitudinal connotation related to the willingness to assist; it therefore introduces a more psychological dimension that goes beyond the scope of the present work (Bedwell et al. 2017).

In this thesis, I examine how cross-expertise collaboration unfolds within formal organizations. I am particularly interested in understanding how specialists share information, pull their knowledge together, and mutually adjust activities and outputs in situations of interdependent work. The literature review therefore follows this scope. It explores studies on cross-expertise work at the individual, group, and organizational level, while excluding those about inter-organizational relations and open collaboration (Berends et al. 2011, Browning, L. D. et al. 1995, Hardy and Phillips 1998). Similarly, it includes publications examining the factors underpinning cross-expertise collaboration and ignores those studies concerned with the possible benefits of collaboration (e.g., the impact of collaboration on organizational performance) (Hargadon and Bechky 2006, Tell, Fredrik 2011). Finally, as the goal of the thesis is to explore cross-expertise work in existing interdependent arrangements, I disregard studies about new collaborative undertakings, such as those focused on the emergence of organizational alliances (Gardner 2016, Powell et al. 1996).

The Challenges of Working (Heterogeneous Knowledge) Together

Cross-expertise collaboration represents one of the key foundational themes in management and organization scholarship. It has been indeed investigated across decades in settings as diverse as scientific laboratories (Nicolini et al. 2012, Bruns

2013, Cummings 2005), service companies (Contu 2014, Kellogg et al. 2006), manufacturing firms (Carlile 2002, Bechky 2003, Hsiao et al. 2011), and hospitals (DiBenigno and Kellogg 2014, Gaboury et al. 2009, O'Brien et al. 2009). It is particularly popular in the product development literature since integrating heterogeneous types of expertise is one of the key challenges of innovation (Dougherty 1992, Burns and Stalker 1961).

Although specialization is beneficial and even necessary for formal organizations and modern life in general (Durkheim 1984, March and Simon 1958), it comes with its own set of complications. More specifically, specialization results in complications relating to distinct sub-goals, practical concerns, meaning systems, and even identities (Bechky 2003, DiBenigno and Kellogg 2014, Gherardi et al. 1998, Nicolini 2012, Carlile 2002). As Dougherty aptly sums it, specialists "not only know different things, but also know things differently" (Dougherty 1992: 187). Thus, the mere willingness to work together is not sufficient to ensure smooth interactions (Kretschmer and Puranam 2008).

Relying on a common illustration, we may say that specialists might use the same word while understanding it in different ways (Bechky 2003: 324). This is because the unique set of meanings, priorities, and values of distinct experts may impact their relations. As a matter of fact, the literature documents that individuals working across expertise domains struggle to understand each other (Bechky 2003), appreciate the concerns of one another and agree on priorities (Carlile 2002), recognize the contributions of some as valid (Oborn and Dawson 2010), adjust work accordingly to mutual demands (Barley, W. 2015), and generally respect or are willing to assist each other (DiBenigno and Kellogg 2014).

Given these significant challenges, scholars have investigated the role of different factors underpinning the accomplishment of cross-expertise collaboration. Here I examine five overarching themes: (1) the personal characteristics of specialists; (2) the nature of social relations among them; (3) the work environment; (4) material and discursive enabling elements; and (5) coordination mechanisms and practices. Table 1 lists each one of these together with exemplary studies.

Personal Characteristics and Collaborative Work

Some scholars explore the influence of personal characteristics on collaborative work. This topic is mainly diffused among studies with a psychological orientation. These examine the effect of variables such as diversity, team identification, or commitment to superordinate goals in the joint work of specialists (Nakata and Im 2017, Janssen and Xu Huang 2007, Bezrukova et al. 2009, Mannix and Neale 2005, Randel and Jaussi 2003). For example, in a study of cross-functional teams, Randel and Jaussi (2003) explored the relation between the level of identification of specialists to their functional background and the likelihood of them pulling their weight in team activities. Specifically, the authors show that experts who identify strongly with their functional specialization — when in a minority position — make smaller contributions to teams (Randel and Jaussi 2003). In a related manner, although embracing a more social perspective, DiBenigno and Kellogg (2014) examined the demographic characteristics of nurses and PCT technicians in hospitals and found that when they share some form of common background (e.g., same age, gender or immigration status), they are more likely to make an extra effort to help each other.

With a more explicit focus on knowledge dynamics, some researchers suggest that the presence of interactional expertise or t-shaped skills (i.e., a generalist awareness together with a specialist one) facilitate collaboration (Hansen 2013, Gorman, M. E. 2002, 2010, Collins et al. 2007). The overall idea is that when experts possess some familiarity with the knowledge domains of the different individuals involved in a collaborative undertaking, dialogue and exchanges unfold more smoothly. This familiarity, in turn, may emerge out of the continuous relations among experts or of specifically designed strategies such as job rotation (Holland et al. 2000).

The Influence of Social Relations on Cross-Expertise Collaboration

The nature and structure of social relations among experts are both important factors for collaboration. The most popular stream in this group of studies is probably given by the one associated with the notion of social capital. These publications explore how the types and density of ties among experts impact collaborative relations (Courpasson and Clegg 2006). For example, Huang & Newell (2003) studied cross-functional projects in four organizations and found that referrals among experts are central to the development of strong ties which in turn foster a more efficient integration.

Complementary to this, authors with a social psychology orientation focus on the more qualitative dimension of relations (in comparison to their structure). They explore the nature of links among experts, with a focus on, for instance, whether they are characterized by trust and respect (see Adler and Borys 1996, Adler 1999, 2006, 1993a). For example, based on a series of studies of airlines operations and healthcare providers, Gittell shows that the quality of relationships is essential for interdependent professional work. More specifically, her work demonstrates that collaboration thrives when relationships include shared goals, shared knowledge, and mutual respect (Gittell 2009, 2004).

Embracing a more cognitive perspective, some scholars explore the role of transactive memory systems in collaborations (Brandon and Hollingshead 2004, Ren et al. 2006, Jarvenpaa and Majchrzak 2008). Transactive memory systems refer to the way in which groups encode, store, and retrieve knowledge from different domains to accomplish goals, echoing the notion of interactive expertise at a more social level (Tell, Frederik et al. 2016). When experts are aware of "who knows what," achieving specific goals is an easier task (Majchrzak et al. 2007).

The Importance of the Work Environment in Collaboration

Moving the locus of analysis beyond individuals, some academics explore the influence of the work environment in cross-expertise collaboration. They document how the physical setting and the general organizational climate shape the interdependent work of experts. In a classic study, Allen shows the positive correlation of proximity and high levels of communication and interactions (Allen, T. 1977). This insight, captured in the 'Allen' curve, still holds to be true in contemporary environments dominated by communication technologies (Allen, T. and Henn 2007). Indeed, many scholars point out the importance of collocation to fuel interactions among experts — albeit admonishing about its varied outcomes (Lakemond and Berggren 2006, Kahn and McDonough 2003, Van den Bulte and Moenaert 1998, Mark 2002)

In more general terms, scholars investigate the influence of different office layouts on collaboration (Elsbach and Bechky 2007, Fayard and Weeks 2011, Boutellier et al. 2008). For example, Fayard and Weeks suggest that common areas and enclosed spaces with the appropriate infrastructure stimulate chats among workers and foster natural interactions; conversely, undifferentiated open-plan spaces tend to inhibit meaningful conversations (Fayard and Weeks 2011, 2007).

Exploring more symbolic aspects, other academics pay attention to the values and norms in the work environment. They consider the relation of constructs such as culture, social cohesion, and psychological safety with collaboration (Edmonson and Nembhard 2009, Edmondson and Lei 2014, Holland et al. 2000, Eppinger and Chitkara 2006, Nakata and Im 2017). Studies suggest that social and group cohesiveness work as a lubricant for exchanges, by undoing barriers among specialists (Mullen and Copper 1994). In a review, Edmonson and Roloff show that in contexts with high levels of psychological safety, professionals are more likely to share ideas openly, request assistance, and admit problems (Edmondson and Roloff 2017). By the same token, scholars highlight that collaborative technologies (e.g., intranet systems) are fruitless in themselves if organizations do not develop a (collaborative) culture that prizes teamwork and sharing (Majchrzak and Wang, Q. 1996, Eppinger and Chitkara 2006).

The Role of Material and Discursive Elements in Collaboration

Many studies examine the enabling role of material and discursive elements in collaboration. Within this field, a very popular research stream concentrates on the value of artifacts as boundary objects (Barley, W. et al. 2012, Bechky 2003, Carlile 2002, Star and Griesemer 1989). Authors extensively document how these aid professionals from distinct specialties to visualize differences and interdependencies (Carlile 2002), to embrace the perspective of distinct specialists (Boland and Tenkasi 1995), to share knowledge (Swan et al. 2007), and to build common ground (Bechky 2003). Based on alternative theoretical perspectives, other academics investigate epistemic objects, activity objects, and the very material infrastructure for collaboration (Ewenstein and Whyte 2009, McGivern & Dopson, 2010, Nicolini et al. 2012, Swan et al. 2007). In a study of the collaborative work of scientists to develop a new bioreactor, Nicolini and colleagues documented how artifacts may serve as the fuel of collaboration, triggering the interest of experts towards a common goal (i.e., epistemic and activity objects); and organizing their activities and interactions (i.e., infrastructure) (Nicolini et al. 2012).

Taking a more interpersonal approach — as opposed to the interobjective one above (Cetina 1997) — academics investigate the role of human intermediaries in collaboration known as boundary spanners, integrators, and liaisons (Tushman 1977, Mohrman 1993, Levina and Vaast 2005, Lawrence and Lorsch 1967a, 1967b). This cotton-field industry of studies has extensively explored how such individuals link expertise domains (Levina and Vaast 2005), distribute information among individuals (Tushman 1977, Tushman and Nadler 1978), mediate conflicts and decisions (Lawrence and Lorsch 1967b), and synchronize and coordinate activities (Ancona and Caldwell 1990).

As for discursive elements, those who examine them usually concentrate on how dialogue plays a central part in the construction of mutual understanding across experts and in the conciliation of distinct interests (Tsoukas 2009, Mengis and Eppler 2008, Mengis 2007). In a theoretical work, Tsoukas discusses how dialogue plays a central role when experts come together to create new knowledge as it allows them to reflect and reconsider their usual ways of acting (Tsoukas 2009). Similarly, Majchrzak and colleagues studied cross-functional teams and concluded that dialogue was central to combine the contribution of various specialists into an integrated solution (Majchrzak et al. 2012).

Coordination Mechanisms and Practices in Cross-Expertise Collaboration

A significant number of scholars explore the mechanisms and practices to coordinate the collaboration of multiple experts. The first wave of these coordination studies was based on a contingency paradigm and looked at the importance of formal mechanisms, such as plans, rules, and standards in achieving integration (Okhuysen and Bechky 2009, Thompson, J. D. 1967, Van de Ven et al. 1976). Reflecting on that, organizational design scholars discuss how lateral arrangements such as (cross-functional) teams, meetings, matrix structures, and task forces ease interdependent processes involving experts from various specialist areas (Galbraith 1977, 1974, Tushman and Nadler 1978).

Conversely, more recent studies demonstrate a greater concern for the contribution of emergent coordination practices, leaving formal mechanisms in the background (Ben-Menahem et al. 2016, Okhuysen and Bechky 2009, Bechky 2006a). The contribution of emergent coordination practices will be discussed in greater detail later. As an illustration of emergent coordination, in a study of a trauma care unit, Faraj and Xiao (2006) found that when confronted with problematic scenarios, specialists resorted to emerging practices to work out co-dependencies on the go. In a similar vein, other academics examine how experts develop emerging ways to organize their collaboration by themselves — and that doing so is an inherent part of their specialist attributions (Barley, W. 2015, Siedlok et al. 2015). For example, Bruns (2013) researched cross-expertise collaboration in system biology labs and showed that while carrying out specialized activities, scientists employed a set of practices to adjust their work and make outputs mutually compatible.

Authors also document that, in collaborative work, experts not only adapt to the distinct understandings and goals of each other, but they also strive to minimize and transcend differences altogether. That is, they share only the information that is comprehensible to all parties and they integrate their contributions into a loosely coupled manner without much discussion (Majchrzak et al. 2012, Kellogg et al. 2006, Schmickl and Kieser 2008). In a study of an advertising service company, Kellogg and colleagues (2006) discovered that notwithstanding conflicts, the members of four different specialty communities were able to enact a “trading zone” by making their work visible and legible to others and by juxtaposing contributions without requiring justifications.

The Missing Factor: Bureaucracy

As reviewed above, the literature has extensively documented a number of mechanisms that influence cross-expertise collaboration (see Table 1 for a summary of the studies cited according to each section). However, this body of studies significantly neglects — and sometimes misrepresents — the importance of bureaucracy in these processes, even though it may influence virtually all the factors reviewed previously. For example, the extent to which experts are familiar with each other's domain (e.g., interactional expertise) may depend on whether career structures and incentive systems promote cross-expertise learning or not. Similarly, the way in which work is divided in the departments and the reporting lines which have been established in the organizational structure greatly influence how social ties and inter-personal trust develop among specialists. The same consideration applies to the nature of the work environment. Where experts are physically placed in the company and the overall company ethos greatly depends on how their work responsibilities are assigned and monitored.

Bureaucracy may also be intertwined with boundary objects and spanners. Schedules, templates, and other typical bureaucratic apparatuses are part of the many artifacts which have been identified as useful to establish collaboration — even though their impact on the structuration of collaborative activities is not always appreciated (more on this later). Boundary spanners and similar roles might be an attribution of individuals in specific positions in the organizational hierarchy; that is, liaising among experts and integrating them together might be part of the job description for some professionals. Finally, coordination mechanisms, such as teams or meetings, might be structured in a bureaucratic manner with a series of procedures and formal work processes regulating them. By the same token, the (emerging) practices which enable experts to adjust and synchronize their interdependent activities may be governed by official leaders. Before laying down the shortcomings that this inattention towards bureaucracy generates in the literature, I will present my understanding of bureaucracy in the next section and how I employ it to examine collaborative dynamics.

Table 1. Factors Influencing Cross-Expertise Collaboration

Personal Characteristics	Diversity of identities and backgrounds	(DiBenigno and Kellogg 2014, Randel and Jaussi 2003, Bezrukova et al. 2009, Mannix and Neale 2005)
	Team Identification	(Janssen and Xu Huang 2007, Bezrukova et al. 2009)
	Interactional Expertise T-Shaped Skills	(Hansen 2013, Gorman, M. E. 2002, 2010, Collins et al. 2007)
Social Relations	Social Capital	(Tortoriello and Krackhardt 2010, Huang and Newell 2003, Fleming et al. 2007, Brookes et al. 2016)
	Mutual Trust and Respect	(Gittell 2009, 2000, Nakata and Im 2017)
	Transactive Memory Systems	(Brandon and Hollingshead 2004, Ren et al. 2006, Jarvenpaa and Majchrzak 2008)
Work Environment	Physical Space (e.g., collocation)	(Elsbach and Bechky 2007, Fayard and Weeks 2011, Boutellier et al. 2008, Allen, T. and Henn 2007)
	Organizational Climate (e.g., Social Cohesion, Collaborative Culture, Psychological Safety)	(Edmonson and Nembhard 2009, Edmondson and Lei 2014, Holland et al. 2000, Eppinger and Chitkara 2006, Nakata and Im 2017)
Material and Discursive Enabling Elements	Artifacts (e.g., Boundary objects, Activity objects, Epistemic objects)	(Barley, W. 2015, Bechky 2003, Carlile 2002, Star and Griesemer 1989, Leigh Star 2010, Nicolini et al. 2012)
	Boundary Spanners, Integrators and Liaison Roles	(Lawrence and Lorsch 1967a, Levina and Vaast 2005, Mohrman 1993, Tushman 1977)
	Dialogue	(Tsoukas 2009, Mengis and Eppler 2008, Mengis 2007)
Coordination Mechanisms and Practices	Formally-Designed Mechanisms	(Galbraith 1995, Van de Ven et al. 1976, Galbraith 1974)
	Emergent Practices	(Bruns 2013, Faraj and Xiao 2006, Ben-Menahem et al. 2016, Bechky 2006a)

Conceptualizing Bureaucracy and Its Role in Collaboration

Defining Bureaucracy

Bureaucracy is a term that has multiple meanings in the management and organization scholarship (Blau and Scott 1962, Merton 1965, Albrow 1970). Therefore, the first step in its study is to clarify the vocabulary. Excluding the traditional understandings of bureaucracy as red tape, mechanistic settings, and coercive processes, bureaucracy has three main key connotations.

First, bureaucracy is sometimes used as a synonym for officialdom and public servants (i.e., bureaucrats). This represents the original use of the term (Riggs 2016), which was employed with regard to an occupational category that became increasingly central with the advent of the modern state (Albrow 1970). Already from its inception, this use of the term 'bureaucracy' entailed a negative meaning: it was employed ironically to criticize the power of public employees and their interferences over business activities (Starbuck 2005). However, once social analysts started to use it in academic publications (the most significant of them being Weber), the term assumed a more neutral stance (Albrow 1970). Second, bureaucracy refers broadly to public/governmental organizations. That is, establishments which employ public office-holders (Riggs 2016). It is with such term in mind that theorists and individuals in general refer to public services and departments as "a bureaucracy" (e.g., Blau, 1973).

Third, bureaucracy is understood as an administrative system linked to formal rationality — as defined by Weber (1978). That is, a system in which work and organizational processes are bounded by impersonality, calculability, and predictability (Weber 1978, Turner 2006, Gabriel 2008). As such, bureaucracy is part of what Weber understood as the rationalization of modern society, which also encompasses the advent of a monetary economy, of legal codification, and of scientific and technical progress (Kalberg 1980, Bruce and Yearley 2006).

It is with the idea of the rationalization of work in mind that I talk about bureaucracy in this thesis. Thus, while I adopt the generic term 'bureaucracy' and its declinations (e.g., bureaucratic, bureaucratization) throughout the work, this should always be understood as a concept linked to rationalization. More specifically, I use "bureaucracy" in reference to a system in which activities and processes are structured according to clear procedures and rules (instead of ad-hoc solutions, personal will, and 'emergent' mechanisms) and enforced according to rational legal authority (as opposed to tradition, charisma or patrimonialism) making it all more unambiguous, calculable, reliable, and precise (Gajduschek 2003, Weber 1978).

Current Research Approaches in the Study of Bureaucracy

Given the centrality of bureaucracy for the field of management and organizational scholarship, authors have approached the theme from various perspectives. Thus, before presenting the analytical boundaries in which I mobilize bureaucracy, it is useful to present a small panorama of the different research approaches associated with its study.

Bureaucracy as a Domination and Control System

Part of the literature on bureaucracy has examined it as part of a process of domination and control. Bureaucracy, in this context, is usually understood as a mechanism in the hands of management to delimit the autonomy of employees and enforce compliance with procedures. By formalizing work practices and establishing regulations, employees are dispossessed from the control over their work. Bureaucracy is thus perceived as intertwined with power relations and the subjugation of workers who become the (in)famous 'cogs in the machine.'

Among authors who explore bureaucracy in light of control dynamics, we find a number of studies on the work of professional groups in formal organizations and the extent they are able to maintain their autonomy and sense of worth in bureaucratic environments (for a general commentary, see Gorman and Sandefur 2011). These studies usually examine the extent bureaucracy is an oppressive system or not (Briscoe, 2007), whether it has enabling or coercive effects (Adler, 2006), and whether it provides occupational groups with latitude/flexibility accomplish their work in terms deemed as ideal by established professional values (Bechky and Chung, 2017).

Interest for bureaucracy as a control mechanism is also present among scholars associated with a 'critical' perspective (Adler, Forbes and Willmott 2007). Broadly, these scholars are interested in power dynamics in organizations. Publications associated with this stream of research thus usually discuss whether and how bureaucracy — understood as a managerial system — produces alienation among workers and is linked to the maintenance of inequalities (Adler 2006, 2012, Courpasson 2000, Karreman and Alvesson 2004). Unlike this approach, I am interested in bureaucracy as a 'technical process' (as opposed to a domination mechanism). While I acknowledge that bureaucracy is linked to control and power relations (Robertson, M. and Swan 2004, Clegg and Lounsbury 2009), this goes beyond the scope of the present thesis.

Bureaucracy as an Ideas-System in Society

Another established research approach in the study of bureaucracy investigates it as an overall ideas-system or social value. That is, bureaucracy is understood as a central institution of modern society which promotes rule-based, impersonal administration. In a bureaucratic organization, employees have attributions delimitated according to their position in the organizational hierarchy, and their conduct is delineated according to clear/explicit procedures. Most of the authors associated with this stream of research have a preference for broad historical/philosophical discussions and have examined the role of bureaucracy in maintaining ethical government (Gay 2000), the underlying causes for the advent of specific bureaucratic configurations in organizations (Kallinikos 2004), or the relation between bureaucracy and democracy (Blau 1973).

For example, Paul du Gay, an exponent of this research approach and important analyst of bureaucracy, has shown how much bureaucracy represents a cornerstone of ethical government and social order in general. He examined how bureaucracy constitutes a specific 'life order,' a whole ethos which instills 'office' workers with specific orientations and virtues. More specifically, bureaucracy generates egalitarianism in organizational operations as it makes workers deal with all situations and individuals according to general procedures thus avowing favoritism and similar inequalities. While this perspective on bureaucracy is particularly illuminating (and close to some findings of the present thesis), it does not fit the scope of the present thesis which has a more modest goal. That is, I am not interested in general discussions on the role of bureaucracy in social and organizational dynamics in general. Rather, my study investigates empirically how bureaucracy impacts work processes within a formal organization.

An Alternative Approach: Bureaucracy as The Rationalization of Work

Different from the two previous research orientations discussed above, I explore bureaucracy as linked to the rationalization of work and organization as understood by Weber (1978). As mentioned before, I am not interested in the 'political' dimension of bureaucracy nor in its implications for organizational processes in general. Rather, my goal is to examine how bureaucratic mechanisms shape the ways specialists work together within formal organizations. While the notion of bureaucracy as the rationalization of work has been well-captured by Weber (Weber 1978, Hall 1963), it has been operationalized and studied in different ways in management and organizational scholarship (Udy 1959, Stinchcombe 1959). Thus, in the next pages I spell out in greater detail what it entails to research bureaucracy as rationalization.

Going Beyond Fixed Templates and Ideal-Types of Bureaucracy

I do not take the Weberian ideal-type or any other closed list of attributes as a condition to define bureaucracy (even though I recognize its value as sensitizing concepts in its study) (Clegg and Lounsbury 2009). As Courpasson and Clegg appropriately put it, the ideal type does not correspond to 'reality'; instead, it seeks to condense some of the features of bureaucracy in a model so one can better recognize it in concrete cases (Courpasson and Clegg 2006). Nevertheless, for decades scholars have analyzed bureaucracy according to the fidelity of a given work arrangement compared to the Weberian ideal-type or to simplified versions of it (Donaldson and Luo 2013). For example, they have focused on written documentation (Kessler et al. 2016, Pugh et al. 1968), vertical divisions of labor (Bunderson and Boumgarden 2010, Walsh and Lee 2015), or in the case of earlier scholarship, the existence of staff departments aimed at designing work processes (Stinchcombe 2009). An easy way to illustrate the poverty of relying on this classic ideal-type as a ready-made 'measure' for bureaucracy is to note that probably all modern organizations would be considered as bureaucratic according to the original Weberian standards. Indeed, the very scholars who employ his conceptualization overlook the fact that Weber uses pages of his work to determine the link of bureaucracy to processes which today are taken for granted, such as the separation of the office from the person, contractual relationships, and monetary compensation (Weber 1978).

Provocations aside, the problem lies at a deeper level. To assess and study bureaucracy according to a closed list of characteristics is a misunderstanding. Weber analyzed the 'bureaucratization of bureaucrats in a bureaucracy'. That is, the anatomy of the *rationalization of work* (i.e., bureaucratization) of a precise occupational group (bureaucrats = public officials) within a certain organizational form (bureaucracy = large governmental organizations). Thus, it is sensible to expect that the characteristics he individualized — even though they are still relevant to understand contemporary workplaces — are based on a very specific context (i.e., XIX century public officials). By acknowledging this, it becomes clear that to assess bureaucracy among construction workers in the 1950s (Stinchcombe 1959) or scientists in research labs today (Walsh and Lee 2015) according to the extent to which they fit the characteristics of public officials in the last century is a misguided enterprise (see Courpasson and Clegg 2006: 322).

Therefore, I contend that instead of investigating the presence of certain pre-determined elements in a setting (e.g., written records), when studying bureaucracy, we should explore whether and how they are intertwined with, and contribute to, the rationalization of work in a given situation. As Gouldner has long noted, we should not take the Weberian ideal-type as a complete tool to understand bureaucracy, but as a suggestive guide for research; a conceptualization subordinated to the actual observations of how work processes in organizations operate in a more or less rationalized (bureaucratized) manner (Gouldner 1952).

Uncertainty Reduction as the Key Characteristic of Bureaucracy

According to Weber, rationalization is geared towards the reduction of uncertainty. In other words, the aim is to make work and organizations more unambiguous, calculable, reliable, and precise (see Gajduschek 2003). This is in stark contrast to the currently diffused idea, wrongfully linked to Weber, that "efficiency" is the distinctive feature of bureaucracy (Merton 1965, Canales 2014, Perrow 1986, Thompson, V. A. 1965, March and Simon 1958, Stinchcombe 1959, Blau and Scott 1962). This is another misunderstanding regarding the Weberian conceptualization (Leivesley et al. 1994). The term efficiency ('efficienz' in German) was foreign to Weber; he never meant that bureaucracy enables organizations to achieve maximum productivity with minimal waste or speedy outcomes (as efficiency is currently understood) (Albrow 1970).

In the original text of *Economy and Society*, Weber wrote that bureaucracy is the most (formally) rational organization form which had ever existed by then, not the most efficient one, as it is usually assumed to be by organizational scholars (Albrow 1970: 64, Gajduschek 2003: 722). As interpreters of bureaucracy have already proved, bureaucracy as defined by Weber may be better understood as a machine to "minimize uncertainty both in [workers'] outputs (what they do) and in [workers'] procedures (how they do it)" and is best linked to features such as "precision, stability, reliability, calculability, unambiguity" (Gajduschek 2003: 715).

The focus on efficiency is likely to be due to translating errors and possibly a reading of Weber associated with modern authors who were primarily concerned with productivity, including Taylor among others (Taylor 1911). Taylor did talk about efficiency (and productivity, as expected from an engineer) and documented the rationalization of manufacturing production (Littler 1978). The fact that Weber became known in the English-speaking universe (and then globally) when the work of Taylor was already famous may have led scholars to treat it as a "descriptive version of the Taylorian organizational model" (Gajduschek 2003: 702). Undoubtedly, there are parallels between the Weberian conceptualization of bureaucracy and scientific management (see for example Adler 1993a); and uncertainty reduction may indeed lead to efficiency (Gajduschek 2003). However, to assess bureaucracy in such manner is theoretically unjust (not least because uncertainty reduction is not an insignificant objective, especially in complex environments). It denies bureaucracy its actual value and hampers a proper understanding of its functioning.

Standing on the Shoulders of Scholars: Weber, Gouldner, and Adler

Besides Weber, with this understanding of bureaucracy, I stand on the shoulders of two scholars who have empirically examined bureaucracy as the rationalization of work: namely, Alvin Gouldner and Paul Adler. They discussed (and showed) the plurality of bureaucracy, stressing the need to go beyond preconceived notions. Gouldner (1964) is perhaps the academic who best understood bureaucracy as a process of rationalization. He admonished that it should not be reduced to specific attributes (e.g., formal records). Besides this, he was perhaps the first scholar to (empirically) capture the multifaceted nature of bureaucracy in his analysis of different forms of bureaucratization within a single firm (e.g., mock, punishment-centred, and representative bureaucracy).

More recently, Adler recovered some of these insights in a number of theoretical and empirical publications (Adler 2006, Adler et al. 2005, Adler 1999, Adler et al. 1999, Adler 1993a, 1993b, 2012, Adler and Borys 1996). Advancing Gouldner's work, he conceptualizes bureaucracy as an organizational technology in order to harness insights from the literature on technology in organizations. In particular, he claims that bureaucracy can be designed with different goals in mind, including an enabling one. Extending this, and also drawing from studies of technology in the workplace, we may say that as much as any other technology, the outcomes of bureaucracy do not depend on its internal features but on its enactment. That is, bureaucracy (like technology) is not inherently good, evil, enabling, coercive, or detrimental (for collaboration). Therefore, to understand its impact on work and organizational processes — including cross-expertise collaboration — we must study how it operates in practice, preferably in situ and in vivo. In this way we can go beyond the 'metaphysical pathos' that still wraps discussions about bureaucracy (Gouldner 1955).

Examining Bureaucracy in Cross-Expertise Collaboration

As much as bureaucracy is absent from the cross-expertise collaboration literature, scholars of bureaucracy rarely explore the interactions among specialists from different domains in organizations (both Gouldner and Adler focus mostly on single occupational communities, and not on the relations among them). In both early and modern scholarship, bureaucracy is imagined — and studied — as an apparatus to regulate a pyramid-like system of relations (Gittell and Douglass 2012). Preeminence is given to the ways it structures vertical relationships at the expense of lateral ones (with some going as far as affirming that lateral relations are absent in bureaucratic environments — this will be discussed in greater detail later) (Heckscher 2015, Weber 1978, Volti 2008).

For example, in his classic study of a gypsum plant, Gouldner explored how the power dynamics at the top of the organization (i.e., the arrival of a new director), and the differences between work settings (mine vs. factory) have influenced interactions among managers and workers (Gouldner 1964). Here we learn much about the various types and degrees of formalization and how they facilitate or strain vertical relations, but little on how bureaucracy influences lateral interactions among employees. Contemporary scholarship follows the same perspective. Emphasis falls on the way in which bureaucratization (re)configures the activities of discreet expert groups, while overlooking how it may impact interdependent work across specialist communities (Huising 2014, Brivot 2011).

The silence over the impact of bureaucratization on cross-expertise work can be traced back to the canonic theorists of bureaucracy who investigated situations in which tasks were apparently limited to specific departments. As Landsberg sums it up, with regard to horizontal (lateral) relations in bureaucracy:

> Max Weber … showed so little interest in the relation between functions. … he was primarily interested in government bureaucracies. … There may have been less, and there may still be less, horizontal 'work flow' required by the 'technology' to achieve the organization's goal in government as compared with industry (Landsberger 1961: 307).

According to the author, early scholars of bureaucracy overlooked lateral relations because they were mostly concerned with governmental organizations. In contrast to this point, contemporary organizations are characterized by distributed work processes and high levels of knowledge specialization, thus requiring a broad range of experts to interact together to get work done (Okhuysen and Bechky 2009). Contexts such as product development specifically depend on the processing of large amounts of information that circulate across various areas (Altfeld 2010, Argyres

1999). For this reason, we need to expand our understanding of bureaucracy to fully grasp its role in contemporary organizations (especially when studying collaboration). When work unfolds sideways, as much as upwards and downwards, there is no reason not to expect bureaucracy to shape lateral process, as it is traditionally assumed to do so on the vertical organizational axis.

Indeed, this thesis explores the impact of bureaucracy in the lateral and vertical dynamics involved in cross-expertise collaboration. More specifically, I will examine whether and how interactions and exchanges among experts might be formalized and subject to the governance of specific professionals. My main contention, following Weber and related analysts (see above), is that bureaucracy may make interdependencies across organizational units more predictable, calculable, disciplined, and unambiguous the same way it is known to do so with work within organizational departments and professional groups.

In closing my exegesis on bureaucracy, I would like to offer some justifications for my choice of the use of this notion. Some may argue that employing the concept of "rationalization" directly would be more straightforward. Also, there are several more contemporary notions that partially describe the rationalization of lateral relations, such as "interdependent process management" (see Adler et al. 2011, Heckscher 2007). Nevertheless, I insist on sticking to bureaucracy and to its declinations because the present thesis aims precisely at fuelling an adequate understanding of bureaucracy as rationalization; and showing that this process may be enmeshed in any organizational and work arrangement — be it vertical, horizontal, in teams, or at the individual level. To employ another term would mean abandoning this important scholarly project.

The Eclipse of Bureaucracy in The Collaboration Literature

In the first section of this chapter I proposed that bureaucracy is absent in the vast literature on cross-expertise collaboration. Moreover, when organizational scholars do pay attention to it, they tend to espouse a limited understanding of bureaucracy; they may discuss its positive/negative impacts on collaborative work, but they overlook how these are exactly produced. After presenting the precise ways in which I understand bureaucracy in the previous sections, here, I shall highlight the ways in which the extant literature has neglected, rejected, and at times even misconceptualized bureaucracy, while explaining how the current thesis shall address these shortcomings.

Highlighting the Neglect and Rejection of Bureaucracy

Most organizational studies seem built on the assumption that cross-expertise collaboration takes place in an organizational void: unfettered from departmental affiliations, work processes, and managers (see Chompalov et al. 2002 for a similar argument). What is depicted in publications are usually situations where everything hinges on the specialists' abilities to work together, to self-organize their interdependencies, and to sort through barriers with emergent practices (Barley, W. 2015, Bechky 2003, Ben-Menahem et al. 2016, Bruns 2013, Carlile 2002, DiBenigno and Kellogg 2014, Kellogg et al. 2006, Kaplan et al. 2016, Nicolini et al. 2012). Even from studies about settings in which regulations and formal processes are undeniably prevalent, such as hospitals and manufacturing organizations, we do not learn much about the governance and control of cross-expertise relations nor about the role of official leaders, procedures, formalization, routines, and the organizational structure (Bechky 2003, DiBenigno and Kellogg 2014, Hsiao et al. 2011). As a result, our comprehension of cross-expertise collaboration is limited since scholars overlook the bureaucratic texture through which experts interact, exchange, and integrate their know-how.

Interestingly, earlier scholars of bureaucracy have already hinted at this issue: Crozier alerted long ago for the risk of "study[ing] interactions in their most physical aspect, without taking into account the hierarchical system" (2010 [1964]: 147). Similarly, Vaughan denounced the narrow focus on interactions in themselves in studies on (technical) knowledge work (the basis of the scholarship on cross-expertise collaboration) (see Vaughan 1999). Translated to our context, we may say that scholars of collaboration across expertise domains extensively investigate how experts share knowledge, problem-solve together, and adjust their activities. Yet, they overlook whether these information exchanges unfold through formalized processes, whether joint analyses involve procedures, and whether official leaders mediate adjustments.

Scholars speak of collaborative processes as if they were unrelated to bureaucracy. For example, consider the stream of studies on boundary spanners, liaisons, integrators and similar intermediaries (Tortoriello et al. 2012, Tushman 1977, Lawrence and Lorsch 1967b, Mohrman 1993, Mintzberg 1979). These studies ignore the relation between individuals performing such roles and formal hierarchy; the impression one gets from reading them is that intermediaries exist outside the charts. To be sure, some scholars differentiate between individuals who have been formally assigned a boundary-spanning or integration role from others who perform it out of a personal interest (Levina and Vaast 2005). Nevertheless, most remain unclear on whether an official position — like an "office" — exists in the organizational structure for individuals carrying out such roles (Weber 1978).

Similarly, studies on cross-functional meetings tend to ignore how much bureaucracy might be involved in them. Organizational researchers have documented how experts struggle in meetings to carve out space for their contributions (Oborn and Dawson 2010), to exchange and integrate ideas in a swift manner (Majchrzak et al. 2012), to jointly assess contributions and suggestions present by peers (Tuertscher et al. 2014) and to come together to synchronize activities (Ben-Menahem et al. 2016). However, they tell us little about the role of any official leader, procedure, standard, or regulation — even in the case of structured events, such as design reviews.

This is unfortunate since such bureaucratic elements may substantially influence the way in which meetings take place (Hull 2012, Vaughan 1999, Briscoe 2007). For example, experts' ability to express concerns may depend on whether there are appointed workers chairing discussions and mediating turn-taking (cf. Oborn and Dawson 2010); procedures might set expectations and facilitate information exchanges by defining which type of information is relevant and the way it should be presented (cf. Majchrzak et al. 2012); and standards may be used to assess competing ideas (Tuertscher et al. 2014). And, at the most basic level, there might be some regulation of attendance to make sure that all relevant experts are present in important discussions (cf. Ben-Menahem et al. 2016).

Even when bureaucratic elements appear in studies, researchers rarely explore their bureaucratic value. For example, works featuring standards and protocols investigate their semantic or information processing capacities with little attention to their regulatory (bureaucratic) power (Dodgson et al. 2007, Mackintosh and Sandall 2010, Swan et al. 2007, Tushman and Nadler 1978). In a study of product development in a manufacturing company, Carlile conceptualizes standardized forms and methods as boundary objects and shows how they work as a shared language, thus enabling experts to discuss their different concerns (Carlile 2002). Yet, whether the use of such method is monitored/enforced is not discussed here (Blau and Scott 1962). Related to this point, in another study on boundary objects, Yakura (2002) explores timelines — a bureaucratic mechanism par excellence to plan and monitor work (Hodgson and Cicmil 2007). However, she focuses on their symbolic value in enabling experts to visualize and negotiate distinct orientations towards time (instead of, for example, their control dimension).

In more extreme cases, academics seem to actively ignore bureaucratic processes even when they appear intertwined to collaboration dynamics. For example, in a study of aeronautical product development Argyres (1999) highlights how standards, codes, and conventions structure relations among various expert groups; still, paradoxically, he not only refrains from talking about bureaucracy but also declares that these elements are actually "substitutes for it", which is apparently erroneously understood as a centralized decision-making authority (more on misconceptualizations will be presented in later sections) (Argyres 1999: 178).

Besides a disregard for bureaucracy, some authors go as far as opposing its relevance for collaboration altogether. As a sort of bogeyman, bureaucracy is taken as an obstacle for knowledge sharing, mutual assistance, and participative processes — this bias is also strongly present in studies on product development and innovation (Thamhain 2007, Ernst 2002, Brown and Eisenhardt 1995, Burns and Stalker 1961) and in the wider scholarship of knowledge work and its management (Robertson, M. and Swan 2004, Newell et al. 2009). For example, some scholars have suggested that (vertical) hierarchy is antithetical to teamwork and to lateral relations among knowledge communities (Boland and Tenkasi 1995); and that standardization (e.g., timelines, routines, protocols) is inadequate for collaborative undertakings involving innovation (Bruns 2013). To resolve these (imagined) shortcomings, scholars propose to substitute bureaucracy for post-bureaucratic, de-bureaucratized, or network forms of organization (Faraj & Yan, 2009; Kallinikos, 2011; Morgan, 1998). However, those who support such a position overlook the fact that bureaucracy actually exists in many forms, not only the caricatured mechanistic version that they understand it to be. Indeed, according to the way in which it is enacted, hierarchy may enable teamwork, while formalization may foster exchanges and relations among experts (see Pinto et al. 1993, Gittell 2001 for such an argument).

Sources for the Eclipse of Bureaucracy and Ways to Counter It

On one level, it could be argued that the eclipse of bureaucracy simply reflects the theoretical preference of cross-expertise work scholars for (exceptional) cases of ungoverned collaboration (Tuertscher et al. 2014). Indeed, Chompalov proposes, for example, that studies of scientific collaborations disproportionately focus on high-energy particle physics, an outlier scientific field characterized by "non-bureaucratic mechanism of work, lack of over-bearing formal structures, and absence of hard and fast internal rules" (Chompalov et al. 2002: 751). While this bias towards cases in which collaboration is not bureaucratized is certainly significant, there are more comprehensive causes for the tendency of authors to neglect, or even reject, bureaucracy. In particular, I highlight three of them: (1) theoretical shifts that privilege an occupational focus at the expense of an organizational one; (2) a disinterest for formal organizational elements in the current literature; and (3) deep-seated misunderstandings and prejudices towards bureaucracy in general organizational scholarship. I review each one separately below and propose ways to counter them.

The Occupational Dimension Overshadows the Organizational Order

The absence of bureaucracy partially stems from a shift in the study of professional/expert work towards an 'occupational' focus (instead of an organizational one). Scholars have increasingly employed the notions of communities of practice, epistemic communities, and professional communities which reflect an occupational analytical lens privileging the symbolic, inter-personal, and communal aspects of work in organizations (Van Maanen and Barley, S. R. 1982, Anteby et al. 2016). This conceptualization captures well the social worlds comprising unique meanings, understandings, priorities, interests, and identities that emerge among similar specialists (Gherardi et al. 1998, Dougherty 1992). Therefore, it provides a valid tool to investigate the ways in which specialists work out, traverse, and transcend knowledge boundaries to collaborate (Carlile 2002, Majchrzak et al. 2012, Nicolini et al. 2012, Kellogg et al. 2006, DiBenigno and Kellogg 2014).

Alas, a way of seeing is always a way of not seeing. As scholars raised awareness about occupational communities, they bracketed off the bureaucratic dimension in expert work. Those who employ such approaches usually re-frame functional groups as communities (e.g., epistemic community) and pay little attention to their place in the (formal) organizational structure (Kogut and Zander 1992); they also display specialists organizing their activities and interactions on the basis of communal control mechanisms (e.g., occupational values, peer pressure) while leaving organizational process, norms, and procedures in the background (Bechky 2003, Kellogg et al. 2006, Hsiao et al. 2011). For example, in a classic study of a manufacturing organization, Bechky (2003) reports interactions among members from three distinct occupational groups. Yet, the author overlooks the experts' position in the organizational structure and whether there are formal organizational procedures guiding their interactions.

This is problematic because organizations are not negligible containers. The way in which work is assigned, monitored, and interconnected also depends on and is shaped by the organizational order (e.g., hierarchy, formal work processes, standards). The hierarchical position of individuals/occupational communities and their roles in formal corporate processes is linked to specific resources, responsibilities, and connections. Also, while there seems to be an understated assumption that the organizational order by definition constrains professional work (Gorman and Sandefur 2011), the reality is that it may be equally enabling.

For example, monitoring routines may reduce a sense of autonomy, but they might also introduce clearer accountabilities and set mutual expectations among workers (Bunderson and Boumgarden 2010). Similarly, organizational roles and processes can be designed to match occupational ones (e.g., giving formal authority to senior members of a community of specialists). Thus, we should not lose sight of the organizational dimension in the effort of incorporating a sensitivity for occupational dynamics in organization and management scholarship (for a similar argument on the importance of connecting the interaction order with the organizational one see Vaughan 1999) (Bechky 2011, Barley, S. R. and Kunda 2001).

The Fall from Grace of Formal Organizational Elements

The neglect of bureaucracy also stems from the more general demise of formal organization features, recently described as "a sort of amnesia about [their] role … in explaining the functioning, performance, and nature of organizations" (McEvily et al. 2014: 302). More specifically, in studies of interdependent work, it seems that while earlier scholars were much concerned with the value of formally designed organizational structures (e.g., plans, standards) (March and Simon 1958, Thompson, J. D. 1967), recent scholarship has moved to a greater emphasis on informal/emergent elements (Okhuysen and Bechky 2009).

This theoretical turn is understandable to the extent that scholars pushed for a more balanced view, emphasizing that formal elements do not define interactions, but are themselves worked out in context (Faraj and Xiao 2006). As Bechky puts it, "emergent work practices also routinely create, recreate and incorporate organizational structures" (Bechky 2008: 9). However, it seems that the pendulum has swung to the other extreme. Worse yet, a dualism has surfaced, one that poses emerging coordination practices (e.g., adjustment and alignment) and formally-designed elements as mutually exclusive (McEvily et al. 2014: 300). This leads to the common assumption that plans, standards, and all sorts of formal (bureaucratic) apparatuses are, at best, futile in cross-expertise collaboration (cf. Bruns 2013).

To be sure, we might expect that the relevance of formal elements decreases in situations of complex interdependence (see Van de Ven et al. 1976). Nevertheless, this does not mean that they disappear; they persist and may even work as the foundation for emergent practices. Indeed, experts mutually adjusting their activities (Bruns 2013) must first have clarity over their responsibilities and interdependencies vis-à-vis each other; this may, in turn, depend on wok plans and schedules. Thus, there is a clear need for a more integrative perspective that accommodates an attention for formal elements in emergent dynamics.

The Bias Against Bureaucracy

Finally, and perhaps most significantly, the organizational and management literature as a whole is filled with misunderstandings and prejudices against bureaucracy (Adler and Borys 1996, Gouldner 1955). Most authors cling to a narrow view of it as a monolithic 'thing' usually associated with the Weberian ideal-type or similar templates (see for a similar critique Courpasson and Clegg 2006, Clegg and Lounsbury 2009). They reduce it to a system in which relations unfold typically across the vertical hierarchy, and individual behavior is tightly regulated by procedures and norms. This makes bureaucracy appear anachronistic and discrepant from modern organizations, especially for those collaborative dynamics in them which by definition involve lateral interactions and exchanges (Alvesson 2004, Grant 1996, Hansen 1999). As I explained above, this is a gross misunderstanding; to pose bureaucracy and collaboration as antithetical speaks more of the inability of an author to provide an appropriate conceptualization than of bureaucracy itself (Courpasson and Clegg 2006).

There is also a deep-seated tendency to present bureaucracy in a caricatured manner as an overly mechanistic system (Burns and Stalker 1961). Characterized in such way, it has been used many times as a universal scapegoat for shortcomings in collaboration— often without explanations on how they have been generated in the first place (Katz and Martin 1997).

Amidst all this bias against bureaucracy, it is not surprising that scholars not only conceptualize cross-expertise collaboration as a matter of expert communities working together (see above) but it also assumes that it all happens above and beyond bureaucracy (Vaast 2007, Boland and Tenkasi 1995, Nonaka 1994). This is unfortunate. The few authors who took the trouble to go beyond this fog of preconceptions and study bureaucracy in concrete terms have shown that it is a much more varied and multifaceted phenomenon than what has been typically presented in the extant literature (see for example Adler and Borys 1996, Adler 1999, 2006, 1993a). Therefore, there is an urgent need to explore concretely, and more agnostically, how bureaucracy shapes cross-expertise collaboration precisely in practice.

Foregrounding Bureaucracy in Cross-Expertise Collaboration

The previous sections have shown that the literature is characterized by an idealized picture of collaboration coupled with a neglect for bureaucracy, as well as for the organizational dimension and the formal organizational aspects more generally. Thus, on the one hand, there is an assumption that to speak of cross-expertise work is to talk about expert communities who freely and willingly work out their activities and interdependencies without any hierarchy, structures, or procedures (see Chompalov et al. 2002). On the other hand, not only is bureaucracy eclipsed, but it is also taken as unrelated — or even worse detrimental — to collaboration and integration processes at large.

To be fair, a lack of attention for bureaucracy in the study of work across expertise domains is not in itself an issue. Scholarship invariably reduces the complexity of the social world in its search for parsimonious explanations. The problem, however, is that bureaucracy has been omitted for so long — and often without any acknowledgment about this omission — that it currently seems irrelevant in collaboration dynamics. As Perrow (1986) appropriately suggested, we only become attentive to bureaucracy when it 'breaks downs' or causes problems. Throw into the mix the prejudices and misunderstandings against bureaucracy, and the result is that of a scholarship unable to appreciate how much formalization, planning, work processes, monitoring, and similar bureaucratic dynamics matter for cross-expertise collaboration and might be at the basis of processes such as teamwork, integration, information sharing, and mutual adjustment. Put simply, the impression from the literature is that collaboration happens *despite* bureaucracy, when it may unfold *because* of some bureaucratic arrangements are in place.

All this suggests that the time is ripe to thoughtfully incorporate bureaucracy in our understandings of cross-expertise collaboration. This involves not only putting it at center stage but also addressing the misconceptions that plague the current organizational literature. Also, in this thesis, I explore collaboration processes from an organizational-order perspective (instead of an occupational or interactional order) (see Langfred and Rockmann 2016 for a similar strategy). With that, I respond to the call for more grounded (and appreciative) studies of bureaucracy (Adler and Borys

1996) as well as to the general demand to explore the organizational context around group and knowledge processes (Kouchaki et al. 2012, Sergeeva and Andreeva 2016), and recover the attention for formal elements in interdependent work (McEvily et al. 2014, Okhuysen and Bechky 2009, Ben-Menahem et al. 2016).

CHAPTER 3

METHODOLOGY

Carl Hammoud — Examination

Introduction: An Ethnography of Aeronautical Product Development

In this chapter, I present the details about my ethnography in PlaneCo. I start by explaining my case selection and by outlining how aeronautical product development represents an ideal setting to explore the intermesh of bureaucracy and cross-expertise collaboration. I then describe how my fieldwork unfolded in the company, which are the resulting empirical materials, and my abductive analytical strategy. I conclude by presenting some ethical concerns and research limitations.

Case Selection: PlaneCo

To understand the role of bureaucracy in cross-expertise collaboration, I conducted fieldwork in an aeronautical company. This is an ideal setting to unravel the dynamics examined in the present thesis for a number of reasons. First, aeronautical product development is a knowledge-intensive enterprise. It requires a highly-qualified workforce with specialists from various fields (Altfeld 2010). Second, integrating the activities of experts and handling interfaces is a central challenge in this sector (Johnson 2006). Third, aerospace organizations feature a strong degree of formalization (Vaughan 1997). In sum, as industry analysts suggest, in aerospace, many experts work together under a bureaucratic regime (Johnson 2006, 2002, 1997).

The selection of an aeronautical setting is also particularly rich in light of some shortcomings of the extant literature. Cross-expertise collaboration scholars have a tendency to study large research-oriented organizations (Chompalov et al. 2002, Tuertscher et al. 2014, Nicolini et al. 2012, Barley, W. 2015, Bruns 2013). As discussed previously, this emphasis leads to an understanding of collaboration as unfettered from (bureaucratic) structures — a perspective which the present thesis aims to break away from (see Chompalov et al. 2002).

PlaneCo has all the features of a typical aeronautical corporation (Chapter 4 presents more details on the company). Although these characteristics make it a unique case, most of the dynamics I identified in the company are quite common to other organizational contexts. The difference is that in aeronautical product development they are simply more transparently observable (Eisenhardt 1989).

Fieldwork, Rapport, and Empirical Materials

The Research Process

My research evolved according to the main tenets of organizational ethnography (Locke 2011, Van Maanen 1979, 2011, Ybema et al. 2009). After establishing my interest in aeronautical product development, I contacted PlaneCo and confirmed some of my impressions about the aeronautical universe. Access was negotiated with representatives from the engineering unit's process excellence group who are normally responsible for mediating interactions with external organizations, including universities.

After a couple of site visits to plan research logistics and check that the phenomena I was interested was indeed present in the company, I commenced fieldwork in late 2013. The research unfolded in two phases. From October 2013 to March 2014 I conducted a slightly exploratory investigation. I visited PlaneCo three days a week on average, carrying out interviews and participating in a variety of events. A small group of informants/gatekeepers helped me to reach out to representatives from various company areas and signposted noteworthy processes and meetings in light of my research interests. They also acted as a soundboard for emerging ideas and doubts (usually related to the technical concepts and the corporate lingo). My aim at this stage was to gain familiarity with the structure, history, and ethos of the organization. Also, I explored the role of the main groups/specialists in the product development, and I identified the collaborative processes which I later explored as a set of embedded cases.

I then took a break of six months from fieldwork during which I analyzed and reflected on my initial findings. This is when the focus on bureaucracy materialized and when I started to explore the relevant literature, in particular studies which examine bureaucracy as the rationalization of work (Gouldner 1964). Based on a robust conceptualization of bureaucracy, and a general understanding of PlaneCo, I selected eight embedded cases to concentrate my research on.

Fieldwork resumed in October 2014 and lasted until June 2015. This second phase had a more focused and intensive character. I visited the company on a daily basis and established links with an extensive network of contacts. Besides continuing with the interviews, I directed my efforts at observing those events where a number of specialist groups interacted (e.g., cross-domain meetings), while learning about the processes that involved various experts (e.g., knowledge exchange tools), and shadowing workers who were responsible for organizing cross-expertise work (e.g., intermediaries).

Given the complexity and length of aeronautical product development, I attempted to study a selection of projects in which airplanes were at different development stages (e.g., initial design vs. preparation for maiden flight). In particular, I conducted fieldwork in groups who were working towards a handful of commercial and executive planes (I did not have access to military products as these projects have a higher level of secrecy). This gave my study a quasi multi-sited character (despite being in a single organization) as I had to navigate across many company areas — and thus routinely enlist the support of new informants (see Nicolini 2010). In a typical day, I would attend a couple of project meetings in the morning, have lunch with some informants from either auxiliary or technological departments, interview representatives from engineering groups in the afternoon, and drop by different workplaces to ask some quick questions/clarifications. All this while trying to schedule more data gathering opportunities.

As part of access negotiations, I promised the company I would share a feedback report with my overall impressions about collaboration in product development, together with any suggestions I might have regarding improvement opportunities. Thus, six months after the conclusion of fieldwork, and after the first round of data analysis, I returned to PlaneCo for a week to present this feedback. I handed a written report to the gatekeepers and delivered two oral presentations to a selected group of individuals. Both the document and the presentations were well-received. During this week, I also had the chance to clarify some lingering doubts and check on some key insights with informants.

My Position in the Field

I was overtly known in the company as a researcher as stipulated by a scholarly code of ethics (Roulet et al. 2017). Similar to all employees and visitors, I wore a badge which showed my academic affiliation. I also handed a one-page summary about my project to most people I met (this document detailed the goals of my study, stressing its scholarly nature, and reassured participants about anonymity). I presented myself — and was introduced by informants — as someone doing a Ph.D. in social sciences/management who was spending some time in the company to understand how collaboration among different experts in the product development took place. The theme resonated strongly with virtually everyone I encountered; PlaneCo employees stressed its importance and occasionally offered spontaneous reflections and personal stories about cross-expertise collaboration (e.g., "I think co-location helps: are you looking into that? We started doing it here some time ago.").

To build and strengthen rapport with informants, I used the typical tactics known to ethnographers (Feldman et al. 2004, Peticca-Harris et al. 2016, Kunda 2013, Fine 2014). I tried to be as friendly as possible — as Czarniawska notes, a field worker is constant smiling (Czarniawska-Joerges 2007) — and to stress my admiration for PlaneCo and for the aircraft industry in general. To blend in, I used an aircraft pin on my lanyard, like many employees, and I tried to keep abreast of the aeronautical world by subscribing to specialized magazines, and reading publications about PlaneCo and related companies. I also read selected books on the design and management of aircraft products which had been suggested by informants to gain some familiarity with the industry. Finally, being an avid baker, I shared homemade delicacies with PlaneCo workers, bringing cakes to the meetings I attended, and to those I shadowed as gifts (Wax 1972).

The Perks of Being a Social Scientist Among Technical Workers

While in the field, I branded myself — and was subsequently branded — as a sociologist, instead of a management scholar, stressing my interest for the 'social' aspects of the product development work (I have a Bachelor's degree in Sociology). Despite the tangible 'techie' ethos of PlaneCo (or perhaps because of it), this gave me several advantages. First, the sociologist identity seemed exotic to technical workers. It, thus, provoked some curiosity and made them willing to talk to me. Informants seemed particularly interested in sharing ideas with (and asking the opinion of) someone they perceived as an expert on collaboration, a theme they deemed slightly enigmatic for those with a technical mindset.

Second, as a social scientist in a technological context, I had some authorization for being naïve. I could ask questions which someone with a technical training would be frowned upon for making. This was particularly important given that I eventually focused on the 'infrastructural' aspects of collaboration.

Third, not having an engineering or technical training made me appear slightly innocuous. Informants appeared more comfortable with the presence of a 'stranger', when they learned that I did not understand the specific details of their work. As a mere sociologist, I could not judge their abilities to handle technical problems nor comprehend the technical innovations they were working on (around which there is usually much concern for confidentiality reasons).

Fourth, being a social scientist gave me a neutral stance. By not being affiliated to any company area or project — there is no group of sociologists in PlaneCo — it was easier to cultivate ties across the board. Also, by stressing a sociologist identity (instead of a management scholar one), informants perceived me merely as a curious person without any intention of selling services to the company. Some informants explicitly commented that they were glad I was "not a consultant or one of those management folks" who they perceived as individuals usually visiting the company to offer a specific service (which most tech workers appeared to be rather allergic to).

Embedded Cases: Collaboration and Bureaucracy in PlaneCo

Typically, ethnographic studies of cross-expertise collaboration concentrate on specific expert groups and their interactions (Bruns 2013). However, in light of my interest in the organizational order and formal elements (see Chapter 2), I employed an alternative strategy. I focused on the events, processes, artifacts, and individuals which bring together a variety of experts and orchestrate their relations — not so much the specialized work in itself. Thus, I spent most of my time in the field following cross-domain meetings, collaboration tools, and the work of product management teams and other professionals with high level of interfaces. Although I did document the activities and concerns of different engineering and drafting groups, this was mostly to gain an overall understanding of their occupational world. My main research goal was to examine the (organizational) work that makes the cross-expertise collaboration of distinct specialists in PlaneCo possible.

More specifically, I focused on eight embedded cases in which the intermesh of cross-expertise collaboration and bureaucracy is particularly visible (see Table 2). Namely, (1) cross-domain meetings addressing processes and issues with a systemic character; (2) knowledge exchange tools developed in PlaneCo as instruments to structure the circulation of information among experts in the engineering unit; and (3) individuals occupying intermediary positions who facilitate and organize interactions among expert groups. These cases exist in all major aircraft projects in PlaneCo with minor differences. In addition, they reflect the dynamics documented in the extant scholarship on scientific/hi-tech work (e.g., technical meetings) and collaboration (e.g., liaison roles), thus making it possible to trace the connections between previous studies and the empirical materials.

In the next chapters, I unravel the intersection of cross-expertise collaboration and bureaucracy in each one of these cases separately. This enables me to portray the extensive ways in which bureaucracy shapes relations among experts in various situations of the product development in PlaneCo. Presenting the findings in such an 'emic' manner also foregrounds the structure and routines of the engineering unit — which is analytically appropriate given the current focus on the organizational order.

Table 2. Embedded Cases of Bureaucracy and Cross-Expertise Collaboration

Chapter 5 Cross-Domain Meetings	Technical Meetings	Zonal Analysis Meeting	Configuration Control Meetings
Chapter 6 Knowledge Exchanges Tools	Knowledge Sharing Registry	Information Collector Tool	Communication Standards
Chapter 7 Intermediaries	Ambassadors	Coordinators	

Empirical Materials

My fieldwork lasted 13 months. During this time, I collected data via non-participant observation, semi-structured interviews, and documentary sources. This yielded a vast collection of empirical materials which includes general notes from circa 220 days in the company, minutes of 160 meetings, logs from the shadowing of the routine of 10 informants, transcripts of 94 semi-structured interviews, and around 40 drawings produced by informants to represent the company's product development. Table 3 below provides a summary of all data sources, and a table featuring details about all interviews carried out is provided in the appendix at the end of the document (Table 9).

In previously mentioned, during fieldwork, my goal was to collect data from a variety of situations which represented the many facets of the intersection of bureaucracy and cross-expertise collaboration. Thus, I strive to document a number of interactions and events in which such phenomena were particularly visible: meetings, information sharing systems, interactions among experts, and so on. In addition, I strived to gain a 'representative' awareness of the product development in PlaneCo and the role of its various sections in the process.

This lead me to sample individuals to interview and generally talk to from across all ranks and departments. In particular, I explicitly tried to interview junior and senior employees as well as managers from a variety of company areas. A full list of interviewees is provided in the appendix (Table 9). The same logic applied in terms of the people I selected to shadow: seven coordinators, two ambassadors, and one chief product manager. This sample included junior and senior employees who were responsible for a variety of work packages (more on differences among these professionals in chapter 7).

Documentary sources were mainly of two types. First, I relied upon publicly available documents about PlaneCo. Given the high profile of the company, this includes countless materials, such as media reports, books, and even scientific articles by previous researchers. Second, I made use of internal documents such as a company magazine and corporate guidelines (e.g., product development manual).

Taking pictures is strictly forbidden within PlaneCo premises. Therefore, all images presented in the thesis have either been reconstructed from field notes or extracted from industry publications and engineering books. I must thus stress that the picture in the zonal analysis section is not a picture of a real meeting in PlaneCo; it is taken from a pamphlet of a company supplying CATIA software and simply serves to illustrate some characteristics of the meeting.

Table 3. Summary Empirical Materials

Data Type	Total Collected
Field Days	Circa 220 days
Meetings	Circa 160 Meeting Transcripts
Shadowing	10 shadowed workers
Semi-Structured Interviews	94 interviews
Cognitive Mapping	40 drawings of the product development
Documentary Sources	Publications about PlaneCo (including official book about company's history) Internal documents (including company magazine)

The Analytical Path

My analytical strategy followed the central tenets of the interpretive tradition with a particular focus on an abductive approach (Tavory and Timmermans 2013, Timmermans and Tavory 2012, Tavory and Timmermans 2014, Schwartz-Shea and Yanow 2013). Analogous to grounded theory, abductive analysis is an iterative, back and forth movement between data and theory (Timmermans and Tavory 2012). The approach also places great emphasis on surprising research evidence and on the cultivation of several theoretical explanations as the researcher makes sense of results. Data analysis, therefore, takes the form of an ampliative form of reasoning in which the researcher aims to turn unexpected findings into coherent theoretical explanations (Mantere and Ketokivi 2012).

As typical of ethnography, analysis started already while I was in the field. As mentioned previously, during my fieldwork I focused on cases in which the intermesh of cross-expertise collaboration and bureaucracy was significantly present, while remaining attentive to explore those situations that could disprove my emerging findings. Upon the conclusion of data collection, I analyzed the resulting empirical materials in the following way.

First, I read and openly coded all materials. I read the 'raw' field notes, interview transcripts, and documents; made sense of drawings; and checked the theoretical memos I had written while in the field. The goal was to reflect on the overall dynamics I had observed, to identify clear themes, and to explore their link with the literature. During this stage, I noticed that while there were many overlaps across embedded cases, there were also unique characteristics to warrant analyzing them as microcosms in themselves.

In a second stage, I examined the collaborative dynamics within the embedded cases (cross-domain meetings, knowledge exchange tools, and intermediaries), while mapping their links to bureaucracy. I soon noticed that this required me to develop a clear conceptualization of bureaucracy as its roles in the above processes were not self-evident. Thus, in the spirit of abduction, I attempted to harness the work of previous studies to better understand my findings. Eventually, I embraced a conceptualization grounded on Weber which takes bureaucracy in the meaning of the rationalization of work (Weber 1978). I discuss this process in more detail in the next sub-section.

Third, I employed the conceptualization of bureaucracy as a system which produces the reduction of uncertainty to interrogate my findings. My goal was to explore whether and how bureaucratic arrangements made collaboration dynamics more predictable and calculable. At this point I noticed how much bureaucracy enabled interactions and exchanges among experts (e.g., it ensured the involvement of specific specialist groups in technical discussions). In contrast to this, the extant literature seemed to be quite critical — or ignorant at best — of the importance of bureaucracy for collaboration. Therefore, I decided to organize the thesis to counter this biased perspective and unearth the value of bureaucracy for work across expertise domains.

In the fourth stage, having established the benefits of bureaucracy in specific situations, I explored the theme across all eight cases. This lead me to identify four enabling roles for cross-expertise collaboration (presented in the discussion chapter).

I then revisited the relevant literature to understand how my findings confirmed, refined, and advanced some positions in the scholarship.

Mobilizing Bureaucracy in the Analytical Process

As mentioned before, following the spirit of abduction, analysis unfolded in an interactive cycle between data analysis and attempts to conceptualize findings according to varying frameworks. In particular, my broad conceptualization of bureaucracy as the rationalization of work and its influence in cross-expertise collaboration emerged after exploring alternative conceptualizations. Below I detail how this process unfolded.

As I started to analyze my data, I searched for existing conceptualizations of bureaucracy in the literature which could aid me to tease out the way in which it influenced collaboration in PlaneCo. It soon occurred to me that an understanding of bureaucracy as a domination and control system did not capture the dynamics which I had observed in PlaneCo. While it is true that some procedures and bureaucratic devices I had documented were directly imposed by management, many had been established in consultation with them. In addition, there were even cases in which the formalization of interactions among specialist had been championed by employees themselves (see chapter 6). Put simply, bureaucratization seemed to serve not only as a domination mechanism but also as a way to make relations more egalitarian in the workplace.

This notion is close to the conceptualization of bureaucracy as an ideas-system advanced by some authors and previously discussed in the literature review (e.g., Gay, 2000). However, such a conceptualization did not provide me with enough of a 'methodological handle' to understand the way bureaucracy operated in the situations I had concretely observed (what exactly counted as bureaucratic?). Thus, in order to advance in my analysis, I attempted to utilize a more 'concrete' framework that spelled out which elements characterize a bureaucratic environment.

This lead me to try analyzing my data using traditional variables associated with bureaucracy as defined in what is known as the Weberian ideal type and used in many empirical studies (i.e., formalization, vertical hierarchy, written documents, and so on) (Donaldson and Luo 2013). However, soon it became apparent that such 'fixed' characteristics did not account for the multifaceted ways in which bureaucracy appeared in the data (for a critique of the use of the Weberian ideal-type in the analysis of bureaucracy, see Clegg and Lounsbury 2009). Basically, this way of understanding bureaucracy was too limiting: bureaucracy was present in some situations as a form to be filled and in others as a fully-fledged formal workflow. For example, I had observed how a very bureaucratized system to exchange information operated (see chapter 5). However, the bureaucratic nature of the system was not given by the existence of written procedures spelling out how the system should function — none existed. Nevertheless, the process was very formalized and associated with specific routines, roles, and records.

Therefore, it became progressively clear to me that what was central to understanding bureaucracy and its influence in collaborative dynamics was not the specific existence of a certain feature (e.g., written documentation). Rather, the fundamental question was examining how a given mechanism made work processes and interactions more rational. That is, how it reduced uncertainty regarding the way work should be carried out, how a meeting should be run, how to request information, and so on. This lead me to embrace a broader conceptualization of bureaucracy anchored on a reading of Weber which poses bureaucratization as a process defined by uncertainty reduction (see Gajduschek 2003).

Ethics and the Importance of Anonymity

During fieldwork informants continually inquired about what outputs the research would lead to and whether PlaneCo would be identifiable in them. As much as employees were supportive of my study, they were also genuinely concerned for any adverse impact it could generate to the company (and themselves). As standard in fieldwork, I promised all informants that I would abide by a rigorous academic code of ethics: under no circumstances I would publicly reveal the identity of the company, and the opinions they shared were confidential and would not be traceable back to them.

Thus, when writing the thesis, I paid particular attention to honor the trust bestowed upon me and maintain the anonymity of PlaneCo and its employees. In particular, given that the number of aircraft manufacturers is quite reduced, I changed the names of most job titles, departments, events, and work tools to disguise PlaneCo as much as possible (the exception are those which are present in virtually all aircraft companies under the same name, e.g., configuration control).

Research Limitations

My study has some significant limitations. While these will be further explored in the final chapter, here I highlight some of its most evident shortcomings. First, as a single fieldworker in an intricate setting, my ability to grasp company processes in their entirety was limited. In particular, since I followed multiple projects across many departments, I sometimes had to opt for breadth, instead of depth, in my data collection. This was particularly true given that my goal was to capture multiple cases which could reveal the various facets of bureaucracy and cross-expertise collaboration in different situations

Second, my fieldwork was conducted in a single organization. Thus, one might argue that the insights it yielded might not be generalizable beyond the specific context of PlaneCo. This is particularly significant given that the highly-regulated and complex nature of aeronautical product development is somewhat unique. Despite all this, I contend that the insights presented in this thesis are applicable to cross-expertise collaboration dynamics in a variety of situations.

CHAPTER 4

THE EMPIRICAL SETTING

PLANECO &

THE ENGINEERING UNIT

Carl Hammoud – Population

Introduction: Engineering, Planes, and Experts

Although in some ways PlaneCo is a typical high-tech company, it also has a number of distinctive characteristics which influence the ways in which bureaucratic arrangements operate. Therefore, before discussing the specific ways in which bureaucracy and collaboration intermesh, I provide an overview of PlaneCo and of the engineering unit in this chapter. I start by presenting the main characteristics of the company, its structure, and ethos. Next, I focus on the work structure in the engineering unit and its main professional categories. Then I explain how the aeronautical product development is organized and what some of its particularities mean for collaboration. I subsequently outline the panorama of the company's expertise and how proper procedures and channels enable specialists to come together, integrate their know-how, share information, and interact with each other (themes which are explored in greater depth in the next three empirical chapters).

PlaneCo in a Nutshell

Company Sections and Leaders

PlaneCo is an industrial organization with thousands of workers. Its shares are traded on the stock market; its offices are spread across continents; its supply chain includes multinational conglomerates as much as small businesses; and its planes fly around the world every day. Company headquarters govern these processes and house specialists working on the products that make it famous. Here we find the engineering unit, the auxiliary departments (e.g. IT, HR, accounting), and the production lines of some of the aircrafts.

There are four positions in the company hierarchy: supervisor, manager, director and vice-president. They are at the head of groups, departments, divisions, and units respectively. Besides these positions, technical professionals may also progress in their career through a separate track. At a mid-career stage, engineers and drafters may attempt to become "technical leaders" instead of competing for managerial posts (most employees prefer the former positions).

Supervisors work in small cubicles or shared offices and are located close to the employees they oversee. They are responsible for administering personnel issues and work activities (they may delegate responsibility for particular undertakings to senior employees). While supervisors are physically and symbolically close to workers, managers occupy a more distant place. Directors and vice-presidents have even less direct contact with employees who often only hear about them when supervisors pass official communications along or when rumors from the upper echelons spread.

Technical leaders are entrusted with preserving and advancing the company's stock of technical knowledge. They support ground-breaking projects, captain task forces, and set directions for new products and technologies. On top of their daily work, they also mentor junior employees, they animate communities of practice, consult on tricky technical issues, and represent the company at industry events. The fact that only technical workers (mainly engineers and drafters) are eligible for this type of career path highlights the importance of these professional groups, who see themselves (and are seen by many) as the soul of PlaneCo.

Procedures, Norms, and Regulations in Abundance

There are enough procedures, rules, regulations, manuals, and standards in PlaneCo to fill a library. This is in part due to the regulated nature of the aeronautical industry which generates standards, rules and guidelines galore. This forces PlaneCo to create a governance system to ensure that work follows the requirements of certification bodies. For example, the details about all the alterations that an aircraft goes through in its commercial life have to be documented and stored; this means that to carry out any technical change, professionals must follow a strict procedure (more on this in Chapter 5).

On top of what is required by law, there seems to be an acquired taste for procedures. Preferring to err on the side of caution, the company is ready to formalize activities that in principle would not need to be formalized. For example, while test planes are not required to abide by the same (stringent) norms of commercially sold ones, PlaneCo has a single procedure for all aircrafts, just in case. Formalizations and controls also appear in normal administrative processes which in principle could be run otherwise.

Commitment and Long-Term Employment

Employees appear to be proud to work for PlaneCo — this feeling is visible in the T-shirts they wear which celebrate the company's achievements. Most employees reveal that they enjoy a good work experience despite the usual shortcomings typical of large corporations and the occasional work stress (which is particularly high around project milestones). As a matter of fact, the company is consistently placed in the top positions of popular rankings of the best workplaces.

Attachment to PlaneCo is partially linked to the allure generated by its products. As a senior manager said in an interview, being involved in the creation of planes is a 'magical' experience for many of his subordinates — and for him as well. The greatest enthusiasts are known to be "bitten by the aeronautics bug." Many employees who I interacted with commented that they spend their free time photographing planes (a hobby known as plane spotting), visiting aero clubs, and building the airplane models that adorn their workstations. Some are even licensed and active pilots, including vice-presidents who are known to spend their Sundays literally up in the air.

Seniority is valued very much throughout the entire company. Senior workers don pins celebrating the time they worked in the company; one of my key informants had one showing he had been there for more than two decades. Seniority is an important dimension in career progression especially for the technical track. As a human resource analyst explained, the underlying idea is that engineers or drafters become really competent in their work after participating in at least a couple of development projects, which by definition are long endeavors.

PlaneCo is keen on retaining its workforce (employee turnover is characterized by low single-digits). There are schemes to encourage the 'recycling' of current personnel and job opportunities are only publicly advertised after internal recruiting does not yield a suitable candidate. Indeed, it is not uncommon for employees, especially technical ones, to spend most of their working life in the company and leaders are usually veterans who have made their way up. Box 1 illustrates the story of a technical leader who has been in PlaneCo for decades and expects young colleagues to continue his mission after his retirement.

Box 1. More Than a Lifetime's Work

> "I joined decades ago as a technician preparing test planes for flights. I then took up some more administrative tasks; I created a system to organize the use of resources in the area and I got a taste for it. I started to study project management and eventually moved to the aircraft program management team. Besides my day-to-day work there, I designed some planning methods which I then started to teach in internal courses across the company. I am now officially recognized as a specialist in this area, and I have been tutoring some younger colleagues. I hope to transfer as much as I know to them. I am probably going to retire within the next decade, but there are still so many things that I would like to do for the company, so I have to trust them to continue carrying the torch I shall pass on." (Technical Leader).

An Engineers' Organization

Engineering is a value in itself at PlaneCo. Since the company's foundation, it has been dominated and run by engineers. They populate positions that in principle would not require such a background. Top leaders including the CEO are above all 'techies' who have acquired management know-how in MBAs and similar executive programs (or on the job after being promoted to managerial functions). Similarly, many heads and some workers from marketing, supply chain, IT and even HR departments have an engineering training. Curiously, I noticed that some of them eagerly 'name-dropped' this fact in meetings.

Although technical expertise is not a requirement for progression in the managerial track, in practice it is very much welcomed. Some informants reported that in their hiring interviews, it proved to be an advantage even if the position did not require it. A supply chain analyst told me an interesting story, reproduced in Box 2, about how he found himself answering technical questions. I must note, however, that despite being an engineers' company, workers seemed well-aware of the perils of overlooking business matters. Many cited as a lesson-not-to-be-forgotten the case of an aircraft project which failed decades ago because it was an engineering wonder without any likely customers.

Box 2. Expected Technical Questions in a Job Interview

"I had applied for a position in the supply chain area; after the usual tests, they scheduled the interview. The director of the department carried it out. He read my CV and saw that I had worked for a telecommunications company. So he started to ask me some questions as if to assess my technical knowledge, even though my position was not a technical one, "why does the reception of my mobile work better in [this place of the city] than [that other place]?", or "why does [a category of mobiles] not support [a type of wireless protocol]?" I had always nurtured a curiosity for technology so luckily I could answer all issues related to frequency bands or data rates, and here I am." (Supply chain analyst)

A Casual and Masculine Universe

An easy going spirit prevails in the company — e.g., workers refer to each other by their first names and nicknames. Most employees eat in the canteens and directors could easily be seen standing in line for food close to technicians (although they were rarely speaking to one another). Important dates are celebrated with little pomp. The greatest of all celebrations are given by the roll-out or maiden flight of an aircraft. While in the field, I participated in one of these events and observed first-hand how tears and smiles were not spared.

Men dominate the workforce, especially in the engineering unit (women are common in HR departments). I rarely saw more than one or two females in project meetings. Grooming styles and attire are sober for both genders. Those working in production don uniforms with indications of the group/assembly line position they belong to (e.g., final painting). Others wear casual office clothes including polo shirts celebrating company accomplishments (e.g., the anniversary of a plane). To fit in, a requirement for any ethnographer, all I needed was a shirt and a pair of black trousers.

Workers usually nurture many ties with peers inside and outside company walls. Besides common social gatherings, people get together in corporate sports teams and even participate in organized travel tours. PlaneCo also employs many couples — and sometimes even their children too. Box 3 features the case of a manager who has some family members in the company. This means that despite its size, PlaneCo feels like a smal(ler) universe for some. Indeed, when I walked with mid-career and senior individuals, I observed that they would easily exchange greetings with half a dozen people from various areas even during a short stroll.

Box 3. PlaneCo as a 'Familiar' Universe

"My husband and I joined the company together after college. That was almost thirty years ago. Throughout all these decades I have seen the maiden flight of every single plane we ever created. The big ones, the small ones, I was there. One of my kids also works here but in another department. The family is split across areas! So the company feels like an extension of my home. I have traveled to many places on behalf of the company, met many people, it is the only place I have ever worked." (Manager)

Techies in Synergy

The PlaneCo universe resonates strongly with earlier studies of tech companies (Dalton 1957, Kanter 1993, Kunda 2006, Leonardi 2012) — the strongest parallel being with the one by Kunda (2006). These document situations in which groups and departments turn into rival 'nation-states' defending their products or becoming self-absorbed in local goals (Christensen 2000, Leonardi 2012, Tett 2015). PlaneCo also suffers from sub-goal optimization, silo thinking, and competition for resources among projects and groups. However, there is also a tangible synergy among its workers: Box 4 features a story that was quite common about the dedication of the workforce especially in critical moments.

This is a central characteristic and one that apparently does not stem from shared values and similar communitarian ideas, as much as from the very nature of work in the company. Unlike places in which individuals are divided into a wide portfolio, in PlaneCo, most efforts are geared towards a very limited number of projects. These are not discrete products that groups can market independently: they all work on sub-systems and components which make up a common output. Tellingly, employees usually joked that a single aircraft system is worthless alone: "[it] does not fly, only an aircraft does."

Box 4. The "We are all in this together" Feeling

"It was a very scary moment; the company shrank to its core. But we had this promising project, and the competencies here do it. The people put in the work; some would come here on weekends, we all felt that either we did it or we died. Eventually, we pulled the company up to where it is today. With every major aircraft, it is the same, we do not have the luxury of failing. If a project does not work, we are gone. And we all want the company to be here tomorrow." (Product Engineer).

An Overview of the Engineering Unit

The Heart of the Company

If PlaneCo is an engineers' company, the engineering unit is its heart. This is where planes are conceptualized, designed and tested. Business units 'contract' the engineering unit which handles the technical aspects of an aircraft throughout its life-cycle. An esteemed vice-president, who has been in the company for decades starting out as a product engineer, leads the unit. Perceived as the 'capital' of the company land, representatives from auxiliary departments usually welcome the opportunity to work in the engineering unit. Box 5 illustrates the story of a production planning analyst who longed to do exactly this.

Technical competence dominates this environment. Workers communicate in a language of their own made up of engineering/aeronautical terms and abbreviations. During my first weeks, I was lost: all the conversations that I had witnessed were peppered with aviation notions (e.g., "the GC of the project"), technical concepts (e.g., "will the FML in the spar 3 impact the MTOW"), and company acronyms (e.g., each department is known by an abbreviation). Eventually I too mastered this local dialect.

New workers usually enter the unit upon completing a professional master's course organized by the company (there is a program for engineers and one for drafters). Admittance is challenging and the program has many stages that mainly assess technical know-how. The degree starts with general classes on aeronautical engineering and participants eventually choose a specialist curriculum (e.g., structural analysis, aerodynamics). At least one-third of the workforce in the unit graduated from these programs.

Box 5. An Employee's Desire to Join the Engineering Unit

"I have been in PlaneCo for a decade now. I joined the manufacturing department just after school. I worked on production planning, an area that I do like. But I had this thing inside me, a desire to join the engineering unit, I even told my boss about it. He found it funny at first, but then an opportunity came up, to join this cross-functional team here, the configuration control committee for this aircraft. He remembered how much I wanted it and I applied. I am so glad, I have been here for a while, and love it, it was really what I wanted. Now I am close to finishing an engineering degree which I have been studying for during the evenings." (Production planning analyst and member of the configuration control board).

The Structure of the Engineering Unit

A Workforce Split Across Divisions

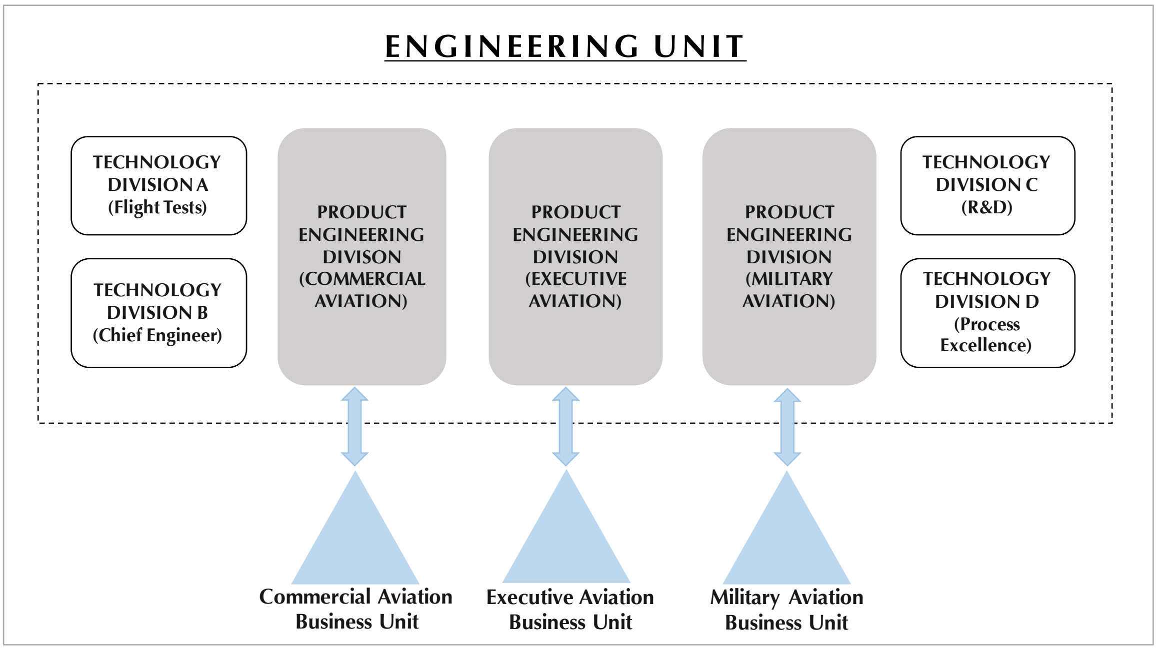
The structure of the engineering unit is intricate and some of its details are confidential (not all employees have access to the full organizational chart). For didactic purposes, we may divide it into two types of divisions: technological (e.g., R&D, Chief engineer's team) and product engineering ones (e.g., commercial aviation product engineering). The former are involved in all aircraft projects while the latter serve specific business units (e.g., commercial aviation). This means that some of its workforce is split into three divisions (i.e., commercial, executive, and military product engineering). Figure 1 provides a visual illustration of this arrangement.

Divisions are quite independent of each other and this often brings the risk of dissonant work practices. This is reduced by the fact that as aircraft projects progress, workload varies, making employees leave projects in which staffing needs are declining and join those in other divisions with an increasing demand for workers. In addition, there are two mechanisms which help to maintain some uniformity: the chief engineer's group and the communities of practice. The chief engineer's team is made up of senior professionals who are responsible for guaranteeing standards in the work of product engineers across the engineering unit. They explore new knowledge, standardize work methods, and act as internal consultants.

This synchronization work is complemented by communities of practice which bring experts together virtually and in person. They are usually populated by individuals from the same domain (only a few have a multidisciplinary audience). They are overseen and periodically assessed by a team of knowledge management specialists from the process excellence group — which carries out activities similar to the chief engineer's office but in relation to the non-technical standards and processes of the product development.

Most employees are spatially located in close proximity to peers with a similar specialization and to their leaders. Cross-functional teams with members seating adjacently are rare. However, to facilitate exchanges, groups with higher levels of co-dependencies tend to be placed nearby. For example, it is common to find structural drafters, structural, and manufacturing engineers involved in the same airframe section sitting close to each other. Also, the majority of divisions and departments of the engineering unit are housed in the headquarters giving the workers the chance to interact extensively face to face.

Figure 1. The Structure of the Engineering Unit



Product Engineering Divisions: Very Functional Matrixes

Traditionally, product engineering divisions had a functional structure which was then replaced by a matrix format in the past decade (see Figure 2). Today, working under the same director, there are both functional departments and product management teams. The latter house on average a dozen employees under a chief product manager. They work in parallel with program management teams from business units which are, as some workers ironically put it, the 'owners' of the planes. While product managers are concerned with the technical aspects of the product development, program managers worry more about commercial issues.

Functional departments break down into groups with circa a couple of dozen people. Individuals are clustered according to specializations and projects (they usually work either on a new aircraft or on certified ones in operation). For example, the airframe engineering department is split into three groups: two focusing on the structural analysis in respectively Plane A (under development) and Plane B (in operation), and another responsible for materials engineering in both Planes A and B.

Conversely, members of a smaller group, such as the safety engineering one, do not present any differentiation. Figure 3 presents these examples visually.

Workers reported to me that the matrix format and the related match between groups and aircraft projects produces a positive esprit de corps. However, the weight of the functional areas is still quite present: the matrix has a 'weak' nature, as career progression and resource allocation is in the hands of functional managers (involved in multiple projects). This means that product management teams have limited control over employees and can be best described as coordinators overseeing cross-functional aspects while tracking work progress in a project (more on their work in Chapter 7).

Figure 2. Matrix in Product Engineering Division

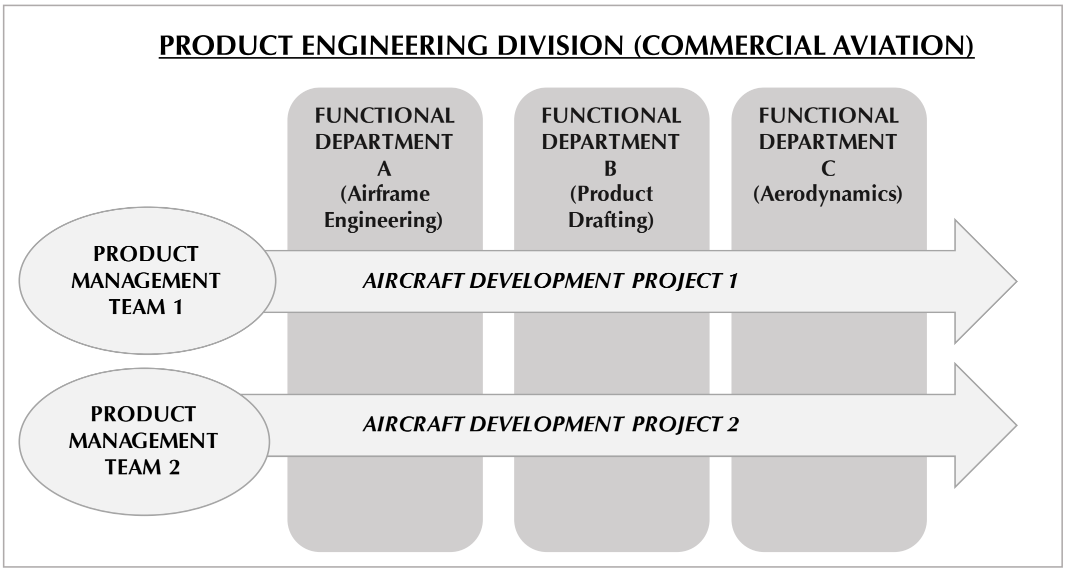
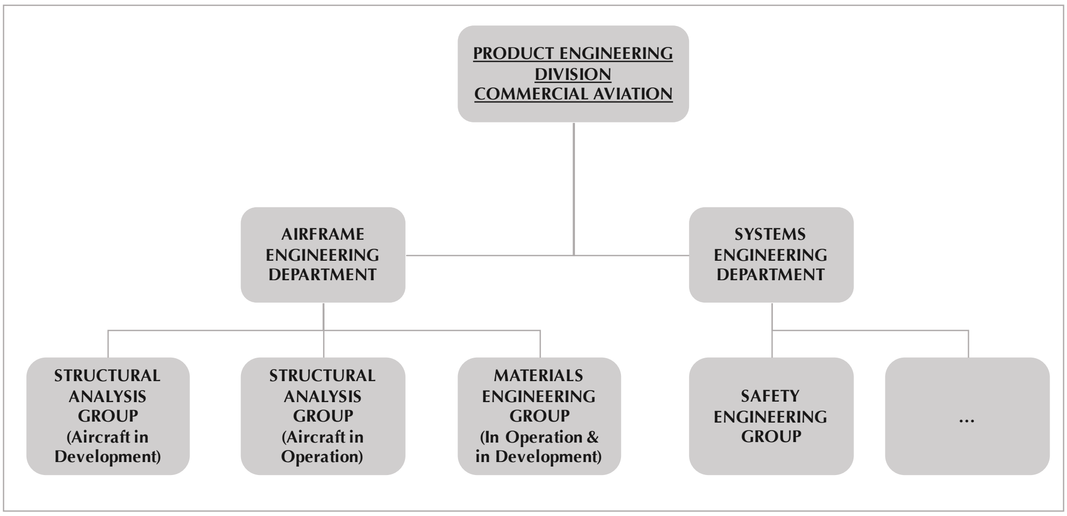


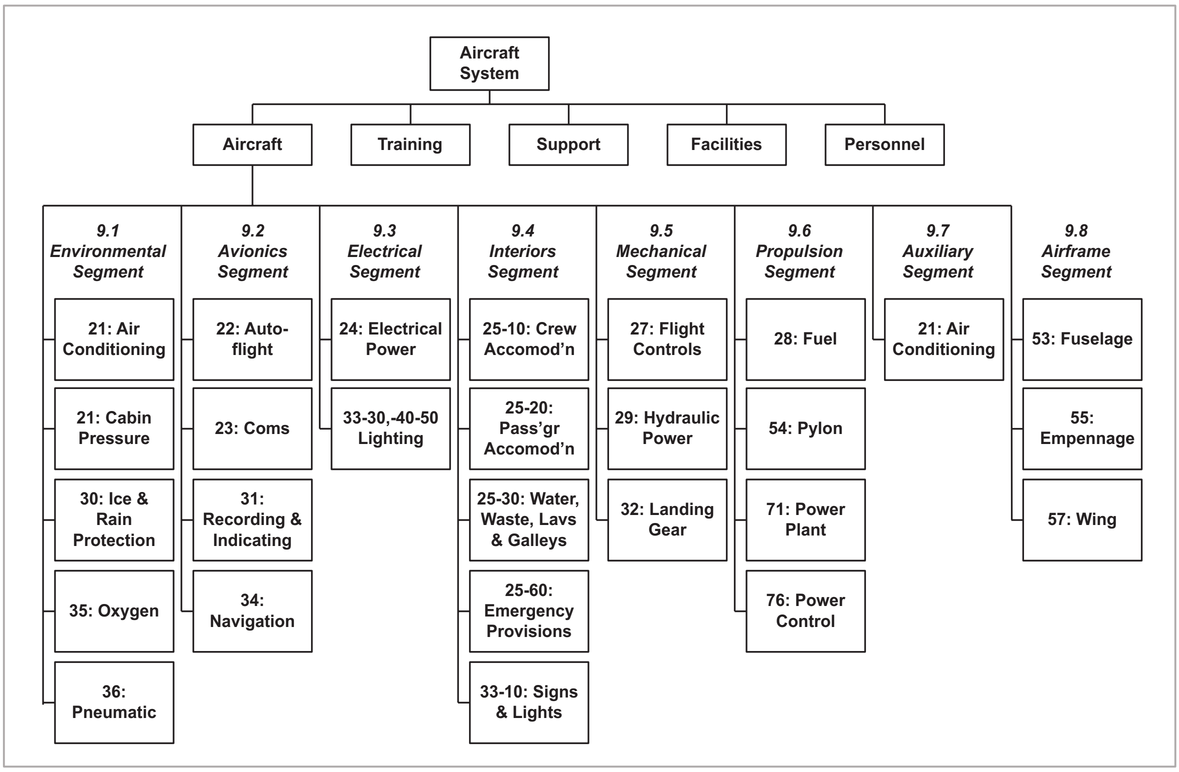
Figure 3. Example of Functional Areas in a Product Engineering Division



Organizational Structure vis-à-vis Product Architecture

As it is typical of tech companies, the organizational structure of the engineering unit matches the product architecture of planes (Howard-Grenville and Carlile 2006, MacCormack et al. 2012). Within product engineering divisions, we find groups who are responsible for discrete aircraft systems (Figure 4 illustrates the key aircraft systems). While some functional groups only include specialists focusing on a single system (e.g., there is a flight control system group), others feature individuals who are responsible for many sub-systems (e.g., there is an ECS group with experts responsible for air conditioning, oxygen, etc.). These arrangements depend on many factors ranging from administrative (e.g., number of employees in a group) to knowledge-related ones (i.e., whether an expertise domain bears commonalities with another). There are also groups working on general aircraft functionalities (e.g., safety) while systemic matters are usually under the responsibility of product management teams (I come back to this when discussing the panorama of expertise in the company).

Figure 4. Aircraft Systems (from Moir and Seabridge 2013)



The People: Engineers, Drafters, and Coordinators

Engineers: Developing and Assessing Aircraft Functionalities

Engineers is the most prestigious professional category in the company. While engineers appear under many job titles, "product engineer" is the most sought after (Box 6 provides an illustration about this theme). It is also the one covering the majority of engineers in the unit which are divided into a number of specializations making up several respective groups. These include aerodynamics, structural analysis, avionics, electric systems, hydro mechanical systems, flight controls systems, propulsion systems, landing gear systems, safety, flight tests, and maintenance.

Product engineers aim to meet specific requirements as they envision technological solutions and assess whether aircraft components and parts function according to their design. Being a regulated industry, safety and reliability are paramount, meaning that these professionals are always busy conducting simulations, writing test scripts, analyzing results, reviewing emerging issues, and so on. Even in the case of components or airframe segments designed/manufactured by suppliers (e.g., turbines), PlaneCo's engineers must still check the work of partners as the company is liable for all the components inside their aircraft.

Box 6. The Prestige of the Product Engineer Title

"Engineer is a title around here. Product engineer then is the one that everyone desires. Some groups even campaigned to have it included in their job description, even though they may work in a non-technical, administrative capacity. Every time one can put 'engineer' in their professional title, rest assured they will do so. As an example, what some may call configuration management in other companies, here we call configuration engineering and so on." (Technical Leader).

Drafters: Drawing Planes into Reality

Drafters are an occupational group made up mostly by technicians. Unlike product engineers, they concentrate on the physical nature of an aircraft. For each aircraft part, there is one drafter responsible for sketching it. As one of them said to me, drafters "make the engineers' dream possible … drawing planes into reality." This is perhaps why some claim that they are the ones pushing the product development (an idea illustrated in the testimonial of a drafter in Box 7). Their work is also divided up according to different sub-systems and components, even though the number of official specialization tracks is reduced when compared to engineers.

A bachelor's degree is not required to work as a drafter and the majority come from technical schools. The ones who have an engineering training have usually obtained it by attending evening courses (yet recently it has become more attractive for trained engineers to join in drafter position). These more qualified professionals (aspire to) occupy higher positions in drafting groups and are more likely to liaise with engineering groups on behalf of peers.

The primary responsibility of drafters is to create technical drawings and three-dimensional models in the digital mock-up. Since design and function go hand in hand, the work of drafters and product engineers is reciprocally interdependent. They create drawings in light of the guidelines from engineers which in turn highlight physical limits, forcing them to expand calculations and propose alternative configurations that are then validated (or not) in (new) technical drawings.

Box 7. Drafters as The Group Pushing the Product Development

"The drafters are the ones pushing product development. It is the same as in any aircraft company. If I were to draw it, we would be at the center of product development. As we start to make it all tangible, to make the dream of engineers come true on the screen, we push forward the relations among experts, the manufacturing engineers, and product engineers, we are there at the factory, touching it; and we are there at the engineer workstations, we demand information that they all need to provide, setting the rhythm of the process. We are the ones close to planes, we draw and see all the parts take shape." (Drafter).

Coordinators: System Level Thinkers

Most coordinators are found in product management groups (their work is discussed more extensively in Chapter 7). They are intermediaries interlacing the work of all experts dispersed across functional areas. It is a position that may be occupied by both engineers and drafters with varying degrees of familiarity with management techniques. As utility players or jack of all trades, some of these professionals at times resemble project managers, while in others they appear more as system integrators (Johnson 1997). Common in either case are the responsibilities for controlling schedules, as much as governing technical problem-solving.

While product engineers and drafters are busy focusing on bits and pieces, calculating and sketching, coordinators worry about pulling it all together in harmony. They are the ones who consider product development projects at a more systemic level, a concern which is illustrated in Box 8, showing the reflection of a coordinator on his long-term interest for developing a broader understanding of aircraft development, while most in PlaneCo settle for narrow specialization.

Box 8. Product Development from a Systems Perspective

"I have always been interested in understanding aircrafts as a whole, not just as a particular system. I am curious in that way. In the professional master's program, I did the classes of two distinct specialization tracks — aerodynamics and structural analysis. There was no time clash, so I did not see why I shouldn't. I work in aerodynamics today, but I go to all the design reviews, these events are like courses about all the different systems of the aircraft. I am hungry to learn more, to gain a systemic perspective, this is the good thing about the coordinator position, I have the chance to be an integrator of all the bits and pieces, to make connections happen, to make information circulate across groups." (Coordinator).

Some Cultural Aspects of the Engineering Unit

A Sense of Urgency

PlaneCo is known in the industry for swift product development, a result of the dedication of its workers and a good dose of pressure. Deadlines are pressing, practically holy, and delay is a four-letter word. This sense of urgency is tangible in task monitoring reviews as much as in corridor talks: build more prototypes, squeeze in another manufacturing shift, bring workers in over the weekends are some of the strategies I heard leaders proposing to keep projects on track.

On the upside, this sense of urgency pushes the company to develop creative strategies to shorten the development process. Like many firms, PlaneCo employs a concurrent engineering arrangement. In addition, urgency is also productive to the extent to which it strengthens commitment and synergy: specialists across departments involved in a project know that they are all in the same boat and seem thrilled to set time records in the industry (on the benefits of deadlines see Magnusson and Lakemond 2011).

On the other hand, urgency is also tied to counterproductive habits. The most salient being the devaluation of careful planning and associated administrative techniques, a drawback illustrated in Box 10 featuring a reflection by a program manager. As expected from a context dominated by "techies," the emphasis is on getting (technical) work done. "Deal with the problems when they happen" seems to be the motto. The result is that sometimes problems that could be avoided turn into emergencies — and there is no shortage of heroes ready to fight such fires (on firefighting and on the vicious cycle of promoting heroic efforts instead of disciplined actions see Repenning and Sterman 2001, Repenning and Gonçalves 2001).

Box 9. Living in the Permanent State of Fire-Fighting

"It is one emergency after the other. It might be intrinsic of engineers; nobody likes taking the time to do an accurate planning, risk assessment and so on. People think that all you need is a time chart. Some even say that the deadlines are so tight that it does not even make sense to worry about it so much, what matters is being able to deal with emergencies. And these are the ones who become famous, the ones that go on to be good fire-fighters. I have to say, we know how to deal with emergencies, it is a skill of its own. Maybe that is why we manage to get it all done eventually, but it creates a really stressful environment" (Program Manager).

Individualized Responsibilities

PlaneCo is a place where praise and blame are many times distributed on an individual basis. Reflecting the (militaristic) propensity of leaders, the idea is to always have someone to hold accountable for the current status of activities. This takes the project management dictum on the importance of clear-cut responsibilities to the next level. Ownership over tasks, issues, processes, and even sub-projects are handed to single individuals, even when these have an apparent interdependent nature. Although apparently controversial, such strategy has some merits. In a place as vast and complex as PlaneCo, activities may easily become everyone's problem but nobody's job. Thus, as a flight test engineer explained, the best way to avoid something getting lost in the company is to have "someone closely watching over it."

This is why, in monitoring meetings, I was at first shocked to see the way in which managers would demand explanations for delays and for other complications in distributed processes and for issues from single individuals. A typical monitoring routine is to put those responsible for work outputs in a room and check charts and task management spreadsheets line by line, while they (must) account for the current status of activities and provide action plans. Reflecting on the overall controlling styles of leaders (and their allergy for delays), anecdotes abound of directors showing up by surprise in monitoring meetings to directly check the status of activities. Box 11 features one of these stories.

Box 10. Top Leaders in a Mundane Monitoring Session

"Once the vice-president of the engineering unit came to that [monitoring] meeting. Everyone was surprised. He asked: 'what is the most delayed technical drawing in the system'. I think it was two months late. He then declared that he wanted it released by the end of the day. This caused a commotion. Everyone argued that it was not an item of high-priority, I think that it depended on suppliers or something like that. Still, he was immovable — you know, he believes in that Lean idea of FIFO [first in - first out]. So the poor [coordinator] responsible for it went around calling people, running through the company and all that. Eventually, he did get it to be released at the end of that same day." (Senior Drafter)

The Product Development in PlaneCo

The Long and Complex Path to Develop Planes

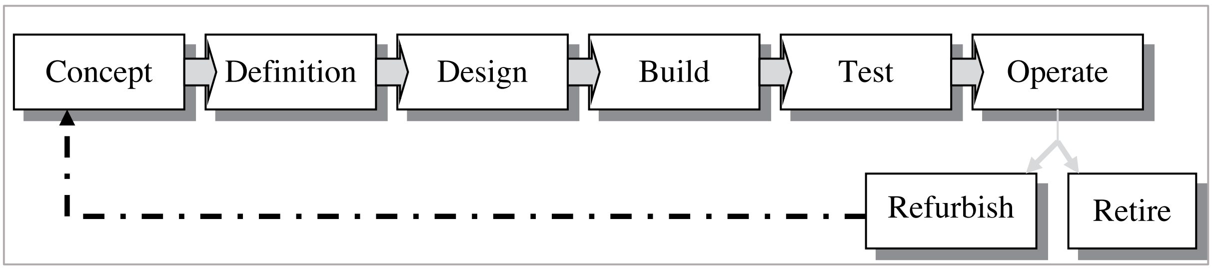
Developing an aircraft is a long and complex enterprise. As an industry analyst put it, these are "top-of-the-learning curve mega-projects" and are characterized by "high financial risks and strong public interest" (Altfeld 2010: 22). It requires not only designing numerous components, but also working out their functional and physical interconnections and carrying out extenuating tests. On top of all this, projects must be on time, scope, and budget (I employ the term project even though 'program' would be more accurate since it involves multiple sub-projects (Altfeld 2010).

Aircrafts, especially commercial ones, are usually developed within a family, i.e., a group of similar aircraft varying in size. Up until the production of the first test planes, the process can be divided into three main phases: conceptual design, preliminary design, and detailed design (see Figure 5). In PlaneCo, in the conceptual stage, the project is in the hands of a small team of professionals with a more generalist knowledge profile and lasts approximately from one to two years. From the get-go, a program management team oversees it all together with a committee made up of representatives from the core company areas (e.g., engineering, manufacturing, customer support, supply chain).

Once the technical and commercial feasibility is established, it becomes a fully-fledged project. From the conceptual division, it is handed to a product engineering one, where it stays for the rest of its life. A chief product manager is then assigned to direct technical aspects and to represent the engineering unit in the above committee. The product management team also joins a board of representatives from technical groups (e.g., structural engineering, flight tests, product design). The chief product manager and program manager usually remain in this position at least until the entry into service of 'their' planes.

Under the direction of the chief product manager, the technical work on the next phases takes place. As design definitions stabilize — and as drawings, production scripts, and test specs emerge — the number of individuals involved grows exponentially to several hundred. All converges into the production of test planes, which go through an extensive test campaign of circa two years leading to their certification. Once the planes are delivered to customers, the product development work is not finished yet. An aircraft can easily be in operation for more than thirty years, undergoing changes throughout this period of time. These may depend on client customizations, changes in technology, and corrections which are revealed to be necessary after further tests.

Figure 5. The Product Development Process



A Manual for the Product Development

The product development is very much a formalized endeavor in PlaneCo. It is a process with specific stages in which activities and deliverables are expected from each group: there are particular moments in which certain analyses are carried out, interfaces with suppliers are defined, design solutions are frozen, technical drawings are released, reports are produced, and so on. Besides these aspects, all this happens according to specific procedures and routines, and technical and administrative leaders review the progress on the basis of pre-set requirements.

Details about phases, deliverables, requirements, procedures, and the responsibilities of groups are documented in guidelines, the most important being the "product development manual." It was created around a decade ago by representatives from all areas of the development process. One of the leads of the initiative explained that it "put what was in people's heads on paper … and established compromises on what would be the product development procedures going forward." The manual is regularly updated and its main points are taught in a course open to all employees.

This formalization creates a backdrop of certainty. It gives workers a general understanding of what is supposed to take place, when, and how. It also provides them with a common vocabulary: its many terms — from the titles of the phases to the names of routines — are on everyone's lips. While most might not read the guidelines themselves, which are available in the intranet, their norms and practices are part of the stock which knowledge workers learn about throughout their career in PlaneCo.

Challenges of Aircraft Development To Collaborative Work

Planes have an integral product architecture: multiple and systemic interdependencies among systems, subsystems and components. Physically, all parts and modules must be fitted into tight spaces, sharing brackets and supporters, while admitting little shimming. Similarly, the functioning of a system is dependent on many other systems. For example, cabin air is made up of recirculated and outside air bled from the engine compressor; thus, besides many other systems, the environmental control system is functionally interdependent to the propulsion one. When trying to give me an idea of these intricacies, a product engineer explained the interconnections of the environmental control system in the following way:

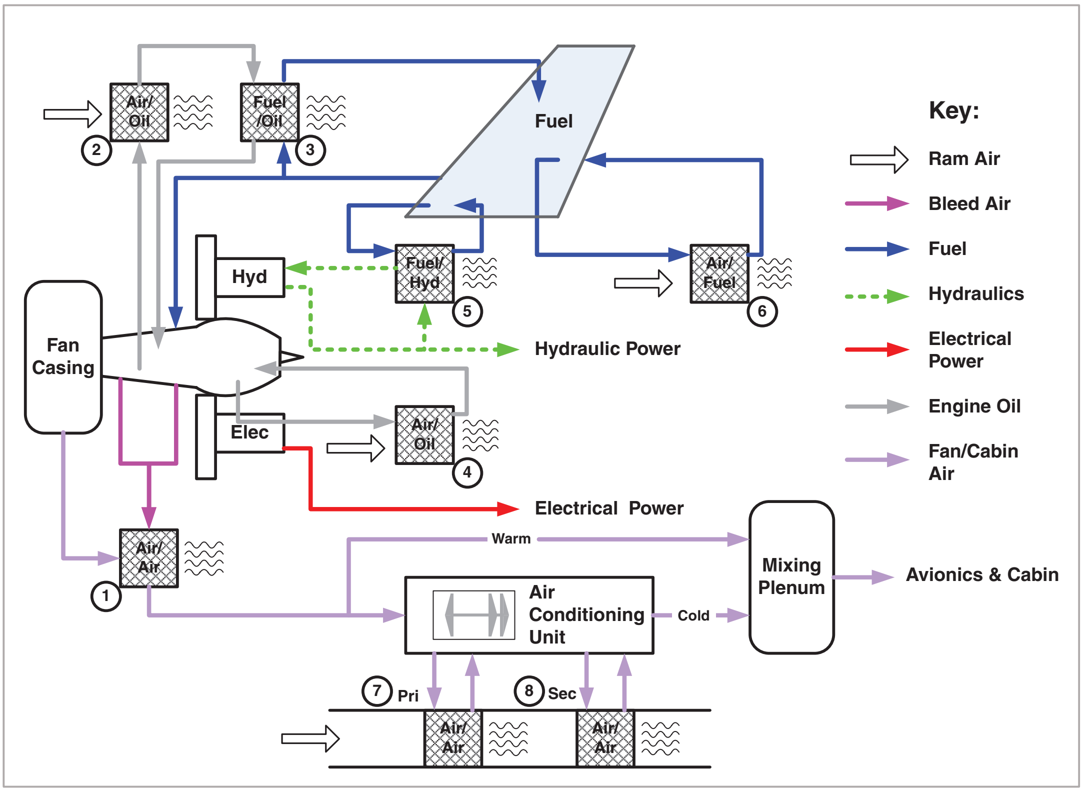
> When in operation, it uses parameters of flight altitude, speed, yoke position, engine condition … inputs from avionics systems, electrical systems, the door status, which impacts in the pressurization, the FADECS [Full Authority Digital

> Engine Control Systems], among others, ok? … I cannot think of a system that it does not interact with, actually.

As the quotation aptly illustrates, an aircraft rightfully deserves the title of a complex system, i.e., one that features many components interacting with each other. Figure 5 below illustrates the relations among some aircraft systems.

The fact that planes are "integrated" systems makes product development work highly-interdependent and generates some particular challenges for collaboration (which are, however, not unique to the aeronautical context). Here I highlight three of them that will be further explored in the next chapters: the need for systemic solutions, the importance of trade-offs to identify optimum designs, and the structuration of the design process in cyclical loops of information.

Figure 6. Interdependencies among Aircraft Systems (from Moir and Seabridge 2013)



Systemic Solutions

The nature of aircraft product development requires that specialists remain attentive to possible ripple consequences of design choices in sub-systems, while aiming at systemic solutions at the same time. Deciding or changing the configuration a single aircraft part may impact a series of related elements and functions. For example, establishing the layout of passenger seats affects the environmental control system: the number of people impact the volume of the necessary intake of outside air, which in turn is tied to the functioning of engines (see example above).

Thus, when deciding among alternative designs or proposing a technical change, experts must map the potential impacts on different systems and incorporate the assessments of the workers who are responsible for them in an inclusive manner (no single person is qualified to assess in detail effects across all systems and components). Experts talked about this issue as that of "integrating the position of various experts" towards systemic solutions (more on this in Chapter 5). Besides contributing to more reliable technical discussions, this reduces the risk of re-working in the future, making the developing process more efficient.

Trade-Offs and Optimum Designs

Design alternatives impact the characteristics of the product differently. For example, cheap airframe materials reduce costs but might increase weight; customized brackets help reliability but reduce manufacturability. Thus, specialists must not only take into account the consequences of proposals in the different systems (see above) but they must also balance them out. This unfolds through a number of trade-offs in which experts present 'hard' evidence to support proposals. Although this is more common during earlier phases, trade-offs arise at any point due to technology problems, change of suppliers, or simply improvement opportunities.

Finding a balanced solution among the viable options is not that straightforward. Specialization leads experts to privilege designs that enhance those characteristics which are familiar to them. For example, structural engineers may focus on reliability gains, while ignoring losses in performance (see Dougherty 1992 on interpretive barriers). In addition, design decisions generate uneven workloads for different groups; this may lead them to (unconsciously) push for alternatives that are more 'comfortable' to them (e.g., thin wings which may alleviate drag for the joy of aerodynamicists, yet prove to be a nightmare for manufacturing engineers to produce). Being well-aware of these risks, experts organize trade-offs and related discussions on the topic to achieve what they describe as "optimum designs," or in more technical terms, "global optimization instead of a local one" (this will be discussed in greater detail in Chapter 5)

Cycles of Information Exchanges and Discussions

Aircraft design unfolds through a number of cycles of information exchanges and debates. As engineers and drafters go from broad definitions to more detailed drawings and calculations, they lead each other to further refine their outputs. The case of the airframe system is exemplary. Structural drafters and engineers establish a preliminary aerodynamic shape used by loads and aeroelasticity engineers to analyze forces and moments impacting structures. Results are used by structural engineers to establish the resistance of the airframe which can then possibly lead to changes in the technical drawings sketched by drafters. These then produce more detailed definitions which are then used by load analysts to produce better calculations, and which in turn re-starts the process. Throughout all of this, the definitions of the airframe impact a whole host of related systems, since the configuration of aircraft parts impact, among other aspects, the available space for components and equipment. In sum, the inputs of certain specialist groups are the outputs of others (this will be explored in greater depth in Chapter 6)

Experts and Layers of Specialization

The Expertise Panorama of the Engineering Unit

Aeronautical product development requires a lot of technical labor — some suggest that aerospace employs the greatest number engineering person-hours of all industries (Altfeld 2010). Besides the sheer amount, it also demands workers with great knowledge depth. In PlaneCo, postgraduate titles are common and highly appreciated and a portion of employees even hold doctoral degrees. Also, there is a lot of knowledge heterogeneity: there are enough expertise fields in the engineering unit to fill a college.

Specializations in PlaneCo have many layers. At a general level, employees are divided into professional groups. The most common in the engineering unit are product engineers and drafters, yet there are also flight tests engineers, support engineers, and manufacturing engineers, among others. Across the company, we find procurement agents, production planning analysts, marketing specialists and so forth. In some professional groups there are also workers who are further specialized in specific domains. These are known as "technical competences" in the engineering unit. Product engineers specialize in dozens of competencies, as manufacturing engineers also do. Drafters only have a handful of specializations, while the majority of other professional groups have none (e.g., support engineers).

In this jungle of knowledge, employees are acquainted with few domains. Although some have connections, which lead them to mature a general understanding of each other, most are only familiar with their own expertise area — not least because performance reviews emphasize knowledge depth, not breadth. Those with a more generalist orientation may find a space as coordinators (some of whom confirm the desire to gain more breadth as the primary motivation for taking up such position — see Box 8 above).

Technical Competencies: The Emphasis on Vertical Specialization

In the panorama of expertise of the engineering unit, the so-called technical competencies are the main coordinates of the entire picture. While technical experts routinely change departments (e.g., product engineers circulate between the chief engineer's office and product engineering divisions), they tend to work within the same competence domain throughout their career. During my time in the field, I only met a couple of product engineers who had specialized in two competence areas.

This emphasis on vertical specialization is encouraged given the metrics used to appraise employees. Besides a regular performance review, some technical workers in the engineering unit are subject to an annual assessment of their abilities. Supervisors carry out the evaluation together with competence gatekeepers (senior workers who also co-lead communities of practice) concentrating on knowledge depth within a certain technical area.

Technical competencies match the structure and functionalities of an aircraft. Product engineers specialize according to aircraft systems and become responsible for their appropriate functioning (e.g., flight control systems are the responsibility of flight control systems specialists); others concentrate on integrated aircraft-level functions, such as safety engineering and aerodynamics; and some specialize on aspects which are common to all product systems, such as maintainability engineering.

Drafters are also grouped according to the systems they design, yet their list of competencies is reduced. Their principal specializations are structures, electrical, and mechanical systems. Mechanical systems drafters are informally divided according to sub-systems (e.g., propulsion system, environmental control system). Table 4 exemplifies the technical competencies of engineers and drafters vis-à-vis aircraft systems (competences which are recognized informally are in brackets).

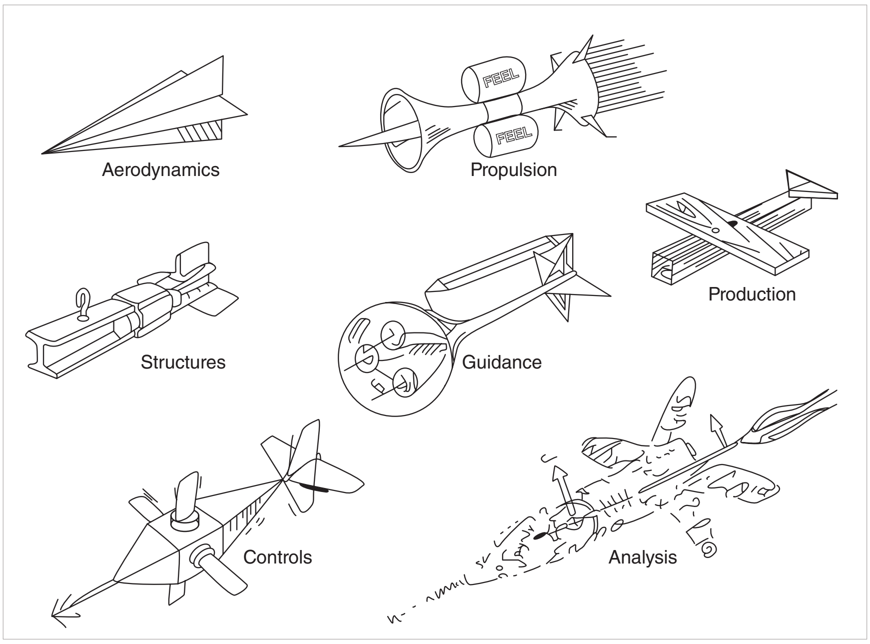
Table 4. Examples of Aircraft Systems and Technical Competences

Aircraft Systems & Functions	Official Engineering Competences	Official Drafting Competences
Aircraft	Aerodynamics	N/A
Aircraft	Safety Engineering	N/A
Cross-System	Maintainability	N/A
Airframe Systems	Structure Materials	Structure Mechanisms
Environmental Control Systems	Oxygen Systems Ice Protection Systems	Mechanical Systems (Environmental Control Systems)
Electrical Systems	Electrical Systems	Electrical Systems
Flight Control Systems	Flight Control Systems	Mechanical Systems (Flight Control System)

Individuals with similar competences are usually clustered in groups (cross-functional teams are rare). For example, engineers specializing on oxygen and ice protection sub-systems are often bundled into an environmental control systems group. In other situations, those with the same competence are divided up usually due to administrative reasons: airframe drafters are split into groups responsible for wing ribs and spars respectively. In some cases, there is a perfect one-to-one matching: safety engineering groups have virtually only safety engineers. In sum, functional groups might hold multiple expertise areas within them.

This functional organization, together with the value of vertical specialization, means that employees work on the same aircraft components throughout most of their careers and make up distinct 'thought worlds' (Dougherty 1992). I witnessed experts many times jesting about the (narrow) understandings of each other. Particularly well-known was an image depicting what would be an "ideal aircraft" according to each expertise domain: for structural engineers, it was boxes and beams joined together, while for aerodynamicists it was all about a sleek and thin configuration. Figure 7 presents an image from a systems engineering book similar to the one that circulated in PlaneCo. The relations among specialists, however, are not merely a joking matter. There is a clear stratification in which engineers, especially product engineers, enjoy a higher status (this will be unraveled more in Chapter 6).

Figure 7. The "Ideal Plane" (from Kossiakoff et al. 2011)



The Importance of Collaboration in PlaneCo

Requisite Integration and The Commitment Towards It

Experts, along with the groups they make up, work on definite aircraft systems. Just as these systems are highly interdependent from each other, so are the activities of the groups developing them. In the words of an informant: "without integration, there are no planes." This illustrates both the fact that planes are made up of the integration of various components and the importance of collaboration among specialists to develop them. For example, cabin pressurization functionality depends on engines and air cycle machines; because these fall within the remit of different groups (i.e., environmental control and propulsion engineers), they must work together to develop and test their designs.

Similarly, the design of a horizontal stabilizer proceeds through cycles of structural calculations, through the drafting of physical parts, and through manufacturing analysis; because structural engineers, drafters, and manufacturing engineers are responsible for each of these tasks respectively, they must work in close association. Collaboration is, thus, a requirement for product development in PlaneCo; we may thus consider it as a context characterized by requisite integration, i.e., a work situation in which integrating tasks and work outputs is not voluntary but a necessity (see Lawrence and Lorsch 1967a).

Besides a requirement, it is, however, also a commitment. Since the beginning of my research, I noticed how much workers felt integration to be paramount. Already during access negotiations, I received this message from an informant after explaining the theme of my study:

> This seems very fitting [studying collaboration in aircraft development]. Specialists [in PlaneCo] have to work in an integrated fashion given the complex nature of the product … the many technical teams aim to work in alignment from the beginning of the product development until the last phases.

During my fieldwork, I observed that this commitment for working "in an integrated fashion" was indeed robust (despite the functional barriers and occasional politics). It was so strong that employees had a whole vocabulary to express it. For example, countless were the times in which they would talk about the following themes: the "alignment" of specialists behind a technical proposal, the importance of groups progressing "in sync" with their activities, shortcomings attributed to the "lack of integration" or to "missing synergies", the need to arrange meetings or get an intermediary to liaise and "put everyone on the same page" or "in the loop", and whether a decision would be "good for the project as whole."

Bureaucracy in Collaboration: Formal Processes for Working Together

Having established how many interactions and exchanges take place in the product development in PlaneCo, the next question is thus how such collaborative work unfolds. Although workers insisted (and I observed) that this was central, they also complained about the lack of unity and about a silo mentality among specialist groups. Some provoked me by saying, "when you find this so-called collaboration you are studying, do let me know about it." Beyond mere banter, this reinforced my impression that some aspects of PlaneCo ran against what is typical in the accounts about cross-expertise collaboration in the literature (Hansen 2009). Cross-functional teams were rare; functional areas controlled the resources despite the matrix organizational structure; job rotation was insignificant; work was divided up, assigned, and controlled by supervisors in a very top down (and militaristic) manner; and workers had (only) incentives to specialize vertically. All this seemed contradictory to what is expected in collaborative work canons.

This left me puzzled. How could cross-expertise collaboration be so central if work in groups was so differentiated, specialized, and individualized? Thus, in a candid moment with a senior engineer, I posed the question openly. His reply was instrumental in unveiling the value of bureaucracy to enable collaboration — and to re-orient my analytical perspective. He looked me straight in the eye and declared: "it all works [in sync] in the end because there are clear rules, procedures, routines to pull it all together and a range of people checking that this does happen."

As I started to learn about these bureaucratic mechanisms organizing collaboration, another striking moment was when a senior drafter spontaneously told me the following about the importance of a formalized tool for collaboration in product design (to be discussed in greater detail in Chapter 6):

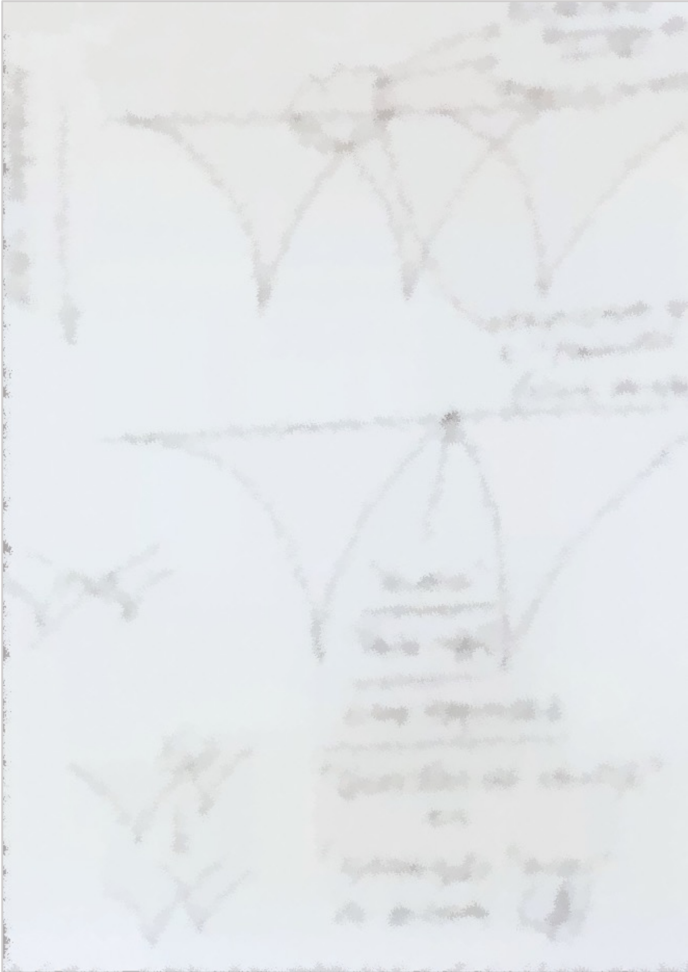
> If processes rely too much on people, problems emerge in relation to the lack of integration, especially among junior workers. Why? Because the person is not mature enough to see the need to call in other specialists, to coordinate work with them, to chat, and to make all this collaboration happen … the [formalization] is meant to avoid having to depend exclusively on people's willingness to work together.

In his words, interactions and exchanges are something to be regulated, and not merely encouraged. While depending on individuals' willingness to collaborate is an uncertain strategy, formal processes make specialists cultivate a collaboration with others that are co-dependent of their activities.

This comprehension of the link between bureaucracy and collaboration reached its peak when I asked the representatives of various groups to draw the company's product development and to explain whether and how they saw collaboration unfolding in it. Following these instructions, a technical leader who had worked in many areas drew rows of upside-down triangles saying that they represented different expert areas (see Figure 8 below). He then circled the intersections of their upper angles and explained that what brought them together (i.e., expert areas) today in PlaneCo were procedures, protocols, routines, and similar formal mechanisms that make sure that experts consult each other when dealing with technical issues, and when reaching decisions, and so on.

These experiences made it blatant that cross-expertise collaboration in PlaneCo was "engineered" in a very bureaucratic manner. As my fieldwork progressed, I discovered and documented the following: experts come together in precise moments and through specific channels, following procedures sustained by technical and administrative leaders; they may exchange information via formalized tools; and they may reach out to each other and adjust their activities with the aid of official intermediaries. I shall explore these phenomena and others which are related in the next chapters.

Figure 8. Worker's Drawing on Collaboration in Product Development



CHAPTER 5

CROSS-DOMAIN MEETINGS

HOW BUREAUCRACY REGULATES EXPERTS' INVOLMENT IN GATHERINGS AND SYSTEMIC PROCESSES

Carl Hammoud – Auditorium

Introduction: Meetings by the Book

During my fieldwork, I found a publication of anecdotes by retired employees at PlaneCo about their experiences in the company some decades ago. One of them talked about the meetings organized by the then vice-president of the engineering unit. It said: "At the start [of that aircraft project], the sheer number of tasks required us to establish a center to pull together all the areas which were involved. This eventually took the form of a daily meeting. The [Engineering VP] commanded it sternly … Every morning, there he was, sitting patiently at the end of a long table … while all the participants had their nerves on edge." After reading this, I became curious about possible similarities between these past meetings and the current ones. So I asked an informant, who had been in PlaneCo for decades, whether he knew about them. To my surprise, he said they were somewhat of a nightmare: an impression shared with other old-timers who I spoke to. That (in)famous Engineering VP did manage to bring together many groups in meetings, but with a cost: everything had to go his way and there was no certainty on what would happen in such gatherings. Stories abounded of the not-so-elegant ways which he used to address the workers, "deriding the contribution of experts to their face … or shouting at someone for bringing up something he deemed irrelevant."

The story above hints at the importance of integrating the contributions of different areas in a complex undertaking, such as aeronautical product development. The challenge is not only to solve technical issues and meet stringent requirements, but also to orchestrate the participation of a multitude of specialists in certain processes. In addition to this, the story also touches upon the perils of bringing workers together, such as in meetings, according to the whims of a leader such as this previous engineering VP. He would make integration happen by decree, by personally deciding which concerns of which groups were relevant. Besides creating distress, such patrimonial system risks degenerating into a situation in which the participation of experts is uncertain and agreements are made on the basis of personal inclinations.

Today in PlaneCo, meetings are still central for cross-expertise collaboration, but much has changed. Senior leaders no longer rule arbitrarily over the ways specialists assemble and deal with interdependent matters (although a degree of militarism is still present, as discussed in the last chapter). A bureaucratic apparatus structures the ways experts come together and integrate their perspectives with regard to technical issues, design alternatives, and change proposals. In short, meetings involving a variety of experts take place very much by the book.

The cross-expertise collaboration literature usually refers to meetings as spontaneous events: structureless situations in which workers touch base, pull together their know-how, and work out common issues (Majchrzak et al. 2012, Barley, W. 2015, Carlile 2002, Kellogg et al. 2006, Truelove and Kellogg 2016, Ben-Menahem et al. 2016). Conversely, my fieldwork revealed that a wide range of procedures, routines, and formal processes actually underpinned the discussions, reviews, problem-solving, and decision-making within and around gatherings. In brief, in PlaneCo meetings are a regulated business. This is the focus of the present chapter which explores how bureaucracy regulates the appropriate involvement of a multitude of experts in three core cross-domain meetings. These are staple events in all product development projects in the company and touch upon systemic matters which in turn depend on the concerted effort of a variety of expert groups. The three cases are organized along a spectrum, from one in which bureaucracy is arguably in the background, towards others in which its role is more fully-fledged.

First, I investigate technical meetings. These are situations where experts discuss technical issues and ways to solve them. Here bureaucracy is visible from the existence of the protocols for such discussions which are in turn monitored by meeting participants and inscribed into definite procedures — i.e., presentation templates and checklists. Second, I explore the zonal analysis, a forum which was initially set out to review the design of aircraft systems and their interconnections in light of a body of safety requirements. It echoes the previously described dynamics but at a larger scale since it brings together a multitude of engineers and drafters (and occasionally also coordinators). Bureaucracy appears more solidly in the zonal analysis (in comparison to the technical meetings) as these are events that unfold in a very routinized manner.

Third, I focus on configuration control, a formalized process involving specialists from divisions well-beyond the engineering unit (e.g., manufacturing, supply chain). In this case, I concentrate on the work of configuration boards and on the meetings in which they analyze change requests, by inspecting — and facilitating — the alignment among specialists potentially impacted by changes. This process oozes bureaucracy: it is centralized in the hands of an 'authority' which applies set-criteria to review change proposals. After examining each of these cases, the chapter presents some concluding remarks.

Technical Meetings: Problem-Solving with Systemic Implications

In this section, I start to unravel the link between bureaucracy and cross-domain meetings. I focus on technical meetings, one of the most emblematic moments for technical work in PlaneCo. In these forums, experts come together to discuss emerging issues and to decide on (competing) technical proposals. I present an overview of the organization of these sessions and examine the bureaucratic role of some procedures, most notably presentation templates and checklists. These procedures make sure that the issues discussed spell out which expert groups are involved, incorporate their inputs, and consider technical alternatives from a holistic perspective. I then discuss how the bureaucratic arrangements of technical meetings make the course of discussions more predictable and increase the clarity of the criteria used to decide on the proposed ideas.

A Hearing for Technical Issues (and the Involvement of Experts)

> Early Monday, a flight tests engineer arrives from another site just in time for the technical meeting; he sits at the back of a room covered with graphs, images, and indicators of a commercial aircraft project. He tells me that he does not foresee much participation by him, since the technical issue to be discussed is just marginally related to his area.
>
> Nearby, we find a program manager, a rare species in the usual crowd of these gatherings. Exhibiting a mix of excitement and concern, he checks his notebook as he waits. He comments that one of the design alternatives may reduce some project costs, thus enhancing the competitiveness of the product.
>
> As representatives from various groups arrive, a coordinator opens a slide presentation and sits by the computer. Close to him, there are leaders/representatives from the structural engineering and drafting groups. They chit chat briefly; the coordinator makes an OK sign to a product engineer apparently referencing a previous agreement. Soon, the chief product manager arrives and the meeting starts.

Technical meetings are the maximum expression of engineering work in PlaneCo — some technical aficionados indeed described them as their "favorite events." In them, engineers and drafters may show (off) their abilities, making sense of problems and reviewing proposals. They exist in all the projects that I studied and are considered to be the main forum to discuss issues which depend on inputs from various expert areas. As summarized by a coordinator, "avionics, engine, manufacturing specialists … all meet in technical meetings." These are the leading places to debate technical problems and to decide upon competing solutions. They deal with a wide variety of themes. Indeed, among others, I had the opportunity to observe discussions about alternative materials for a wing part, small difficulties with some requirements, opportunities for improvement in the design of landing gears, minor problems with suppliers, proposals to resize equipment, and even requests to re-dimension the overall performance of an aircraft. The common denominator of these issues is that they either span many areas of expertise or have a significant impact on the project (e.g., increase in costs).

Technical meetings are organized according to a two-tier system. The ones on the first level are overseen by the product management team and chaired by the chief product manager. They take place periodically, usually twice a week. Presenting at them is a reasonably mundane task. The audience usually includes a dozen of peers, mostly coordinators, supervisors, and ambassadors (occasionally also some technical leaders and managers are present). When issues are intricate (e.g., the implementation of a new technology) or compromise major project characteristics (e.g., changes in macro-level requirements), the chief product manager may escalate them to the chief engineer. This represents a more delicate — and rare — situation (as a matter of fact only a minority of cases get to this stage). In these meetings, the audience is larger and includes the chief engineer, senior specialists from the team, and sometimes directors of the engineering unit. In both situations, the underlying goal is the same: "bring together those who can decide, the groups affected by decisions, the relevant information … in the same place," in the words of a senior coordinator.

More specifically, issues are presented by the individual or team leading its resolution. Using a deck of slides, they introduce the issue, the analyses which have already been undertaken, and when appropriate, the pros and cons of competing solutions. The audience observes, sometimes while taking notes, and intervenes with probing questions, requests for clarification, and counter-arguments. As typical in engineering work, especially in aerospace, the emphasis lies on the hard facts (Vaughan 1997). Slides are peppered with graphs, tables, and simulation results.

These dynamics greatly resemble the ways in which (technical) specialists problem-solve and discuss alternative solutions, as documented by scholars of scientific and technological work (Tuertscher et al. 2014, Owen-Smith 2001). Yet, in PlaneCo it all unfolds in a more regulated manner. The tone, pace, and atmosphere feel as if one were in a legal hearing. There is much apprehension around the 'verdict'; presenters expose and provide 'evidence' for competing ideas; experts are at times called to 'corroborate' an analysis or proposal; and an appointed individual (chief product manager or chief engineer) chairs the discussions. Also, many were the times in which a session concluded with the instruction of holding another meeting or escalating it to a 'higher court.'

In these 'technical tribunals,' issues and associated proposals are not only judged on the basis of their technical merit; in the spirit of optimal solutions, and in light of the systemic nature of planes, they are also evaluated based on how much interfaces have been mapped and accounted for. In other words, whether possible impacts on sub-systems and product characteristics have been analyzed thoroughly by all relevant experts. This is of particular interest for the theme of cross-expertise collaboration and the focus in this section (similar dynamics in configuration control meetings are explored in the following sections).

Keeping Experts in the Loop and Incorporating Their Viewpoints

Problem-solving in technical meetings is expected to proceed with constant attention for systemic interdependencies. This means both being aware of the interconnections of a given issue and being open for suggestions from experts. In the words of a flight engineer, "we try to be in technical meetings … so when we see something potentially problematic we can say 'we know this was a problem in the past, what about trying a different approach?'"

The involvement of a variety of groups is supported by norms stipulating the participation of all relevant specialists. Specialists are well-aware of them and prepare for technical meetings accordingly. They usually refer to this effort with metaphors which relate to the idea of "getting all experts in the loop." Nevertheless, nothing is perfect. Sometimes, either due to the complexity of airplanes, of organizational politics, or both, workers misconceive the impacts of an issue and leave peers 'out of the loop.'

To counter that, the participants at meetings — especially leaders and senior workers — continually judge the 'breadth' of the analyses presented, along with obviously their technical depth (see above). Particularly, the extent to which these incorporate the perspectives of multiple experts. For example, in a discussion about a change in the geometry of an airframe part, a senior coordinator probed the presenter in the following way:

> *Senior Coordinator:* What about structural damage in the case of a bird strike? [there are tests to assess damage of a bird strike on the aircraft hull and engines]
>
> *Presenter:* Well, the proposed change does not alter the physical interfaces between the aft pressure bulkhead and the hull [these are two aircraft sections].
>
> *Senior Coordinator:* Yes, but the propagation of a possible crack might be different if the geometry changes… [propagation is a great concern; structures are designed to reduce them and maintenance checks are set to inspect the cracks].
>
> *Senior Airframe Drafter:* [almost speaking over] Yes, I agree … we need to investigate that further…
>
> *Presenter:* This geometry is actually more robust and has a better distribution [which means it is more reliable].
>
> *Senior Coordinator:* Well, from what you have shown [in the slides] all we know is that it is different! Did someone look at this?
>
> *Presenter:* I mean, it is not explicit in the slides, but I did speak with [an expert on bird strike analysis] and showed him the new geometry … he told me that there is no need for further tests.
>
> *Senior Coordinator:* Ah! In this case, add his analysis to the presentation! It needs to be comprehensive.

This interaction illustrates the concern towards thoroughly mapping the ripple effects of changes and 'harvesting' the viewpoint of related groups. The senior coordinator was worried that the analysis of a specialist on bird strikes was missing. Ironically, as it turned out, such an expert had already been contacted; the presenter had just forgotten or deemed making it explicit unimportant. Nevertheless, the coordinator still asked her to include the position of those consulted in the presentation. In the meetings I observed, this situation was rather typical. Whenever a coordinator, chief product manager, or anyone else deemed that the opinion of an expert area was missing, they would request further studies and that the specialists in question present results in a subsequent gathering. Given the company's spirit of "erring on the side of caution," this was usually taken in a positive way.

Inscribing Concerns for Interdependencies in Routines and Templates

PlaneCo workers display an evident willingness to consider systemic interdependencies and the possible contributions of peers in face of technical issues. Still, as some engineers do like to jest, humans are imperfect machines. Thus project leaders and employees themselves are willing to employ mechanisms to make sure that 'the perspective of no expert is left behind.' In some projects, the strategy seems to be tackling the problem at its root. They establish it as a standard procedure to invite leaders from all groups to every technical meeting. Invitations are distributed via email with the agenda for the session and a general description of the issues to be discussed (the same information is usually available on the project dashboard). The understanding is that the experts themselves are ultimately the most suitable individuals to decide whether their participation is relevant or not.

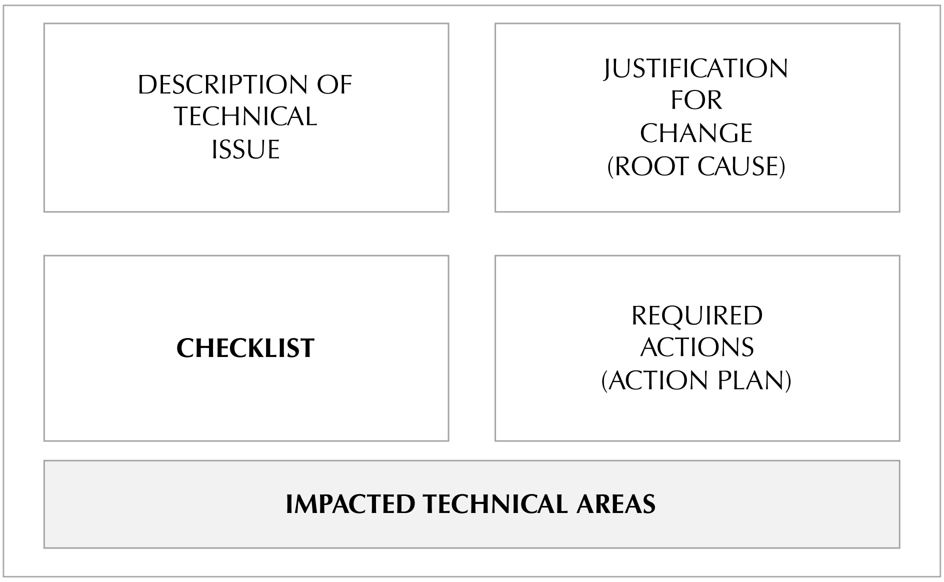
While the idea may appear excessive and does have potentially some downsides (e.g., information overload), it is deemed by some to be the safest one. Some technical specialists also consider it as pushing the "human component" outside the picture and it seems particularly prevalent in projects which had some slips at some point. A chief product manager who employed such practice explained the rationale behind it in the following way:

> We had minor problems earlier in the project when its organization was a bit loose … so now we follow a specific procedure and send invitations to all groups … of course not every issue is relevant to everyone, but the rule is to notify them anyway, just in case.

While inviting all experts is a solution which exists in some projects, there is a more diffused one: using presentation templates which inscribe the concern for interdependencies. Templates, in general, are common in all sort of meetings in the engineering unit. Just like an agenda, they provide some structure for discussions, by organizing information according to what is considered relevant in a situation. For example, a widely-used template for design reviews features pre-set slides to be filled with information vis-à-vis criteria used to assess the status of development work.

The use of a presentation template is not required in technical meetings. The product development manual only establishes that presentations must be done with PowerPoint and outline in a self-contained manner the matter at hand, by listing what is known so far and the possible solutions. Nevertheless, employees seem quite keen to use them. More than once, I overheard coordinators while reflecting on what they would change in the project, saying that the one thing they would keep were the presentation templates. The most common one for technical meetings features a pre-set slide summarizing the topic under discussion. One of its cells asks workers to explicitly list the areas impacted by the technical issue (see "impacted technical areas" on the lower part of Figure 9). This slide is usually among the first to be presented and sets the tone of the conversation.

Figure 9. Technical Meeting Template (reconstructed from field notes)



Although paying so much analytical attention to a simple list of impacted areas may appear strange, it is certainly not insignificant in technical discussions about a product with thousands of components developed by several dozens of expert areas. Pushing workers to be explicit is a way to identify interdependencies and limit the boundaries of the debates. Indeed, it is not rare to find participants using this list to orient themselves. Consider the following interaction at the beginning of a technical meeting with the chief engineer's team:

> *Director:* [reads slide] Root cause, action plan … OK, you wrote that the flight controls system would be impacted by this redesign in the ECS [environmental control system].
>
> *Coordinator:* Yes, flight commands get signals from many systems, including the ECS to assess the aircraft dispatchability [whether a plane is safe to fly or not].
>
> *Senior Engineer:* [in a surprised tone] So the warning would show a fault in flight controls plus the ECS!?
>
> *Coordinator:* No, there is no separate signal for the ECS, it goes straight into a message to the pilot about the status of the flight control system. So we need to take into account the interdependence between these systems.

As the conversation extract shows, the template was instrumental in calling the attention of experts to interdependencies that were apparently unclear. Throughout the meeting, workers (including senior ones) continued to refer to it as they sorted through which systems — and which related experts — would be impacted by a technical reconfiguration.

Besides identifying impacted areas, presentations must also highlight the fact that all specialists to whom the issue is relevant have been consulted and were able to specify their position about it. Again, this protocol is reinforced by the presentation template. In technical meetings, seeing is believing: slides must detail the analyses and conclusions of the pertinent experts. The convention is that for each "impacted area" there should be (at least) one slide displaying these impacts in detail, such as whether there is the risk of not meeting requirements or compromising critical product functionalities.

I noticed first-hand this diligence towards the task of assembling slides that incorporate the viewpoints of different areas when shadowing coordinators and senior members of functional groups. Consider the notes I took when observing Z, a coordinator overseeing the development of the wings of a commercial plane:

> 2 PM: Z is preparing a presentation to propose a significant change in a wing section which houses many systems (e.g., fuel pipes, electrical cables, etc.). He writes an email to a safety engineer reminding him to send over some results related to a certain safety assessment. He then calls a fuel system drafter and asks, in a strict tone, "how come you didn't send [the slides with the technical drawings] yet?" After a negotiation, the drafter promises they will be delivered tomorrow afternoon.
>
> […]

> 4 PM: An email arrives from a safety engineer with the slides Z had asked for. He then calls the engineer. While looking at the slides, Z thanks him for the analysis and for including a justification to why the proposed reconfiguration does not impact safety requirements. Z then confirms that the engineer can come to the meeting next week to deliver his expert opinion — and support — first hand.

As illustrated in the notes above, the coordinator incorporated information from different experts into a deck of slides about some alterations in the airframe. He also orchestrated the presence of some specialists to 'testify' for this particular solution. When the meeting took place, the invited safety engineer presented his assessment which showed that the change was viable.

Achieving Well-Rounded Technical Solutions

Besides interfaces with various systems and experts, individuals must also assess the impact of technical issues on key product/project variables: aircraft performance, maintainability, project costs, deadlines, etc. As discussed in chapter 4, a design solution in aircraft product development invariably enhances certain technical features, while compromising others. For example, a more robust material in the airframe may strengthen its reliability to cracks; however, it will probably increase the overall weight and therefore reduce performance levels. Thus, experts must consider the ups and downs of each solution in a holistic manner when dealing with technical issues.

In reality, attention for optimal solutions should be part of PlaneCo workers' routine (see Chapter 4). All decisions on design, even the smallest, invariably have implications on costs, maintainability, etc. However, it is important to recall that the work structure in PlaneCo is based on narrow specialization. Unless an aircraft project is facing a particular problem (e.g., costs overrun), engineers/drafters focus on fulfilling the technical requirements of the systems and components they design (which is already a lot of work). As a functional manager put it, "our engineers like and are good at engineering … they expect someone else to think about the costs and that stuff."

To balance this, the company tries to raise awareness on the matter. For example, while in the field, I attended a seminar aimed at getting drafters to reflect on how much each and every design configuration has important implications for products/projects in terms of costs, performance, etc. Still, the responsibility for sustaining a focus on optimum solutions in technical discussions mostly falls on the shoulders of coordinators, program managers, and those responsible for aircraft-level issues, such as safety engineers.

Checklists to Promote a Holistic Perspective

Having to depend on the presence of particular experts to raise flags in meetings when proposed solutions are not well-balanced is not ideal (as this is a strategy with too much uncertainty). For this reason, PlaneCo relies on standards which prescribe what should be taken into account when assessing (competing) proposals that take workers beyond their functional (and narrow) perspectives. These are especially common in the early phases of product development when experts make an extensive use of multidisciplinary design optimization and similar techniques to weigh the implications of a design in a holistic manner (Perez et al. 2004, Holt and Barnes 2010).

Focusing on technical meetings, product and program managers publicized a more elementary method that can be used by anyone: a checklist (Figure 10). On many occasions, it appears as part of the presentation template discussed above (see 'checklist' on Figure 9). Although not compulsory, workers deem it to be relevant when examining the strengths/weakness of solutions and making decisions on them in a reliable manner. I managed to observe a senior worker telling trainee engineers the following during an orientation session: "technical discussions without substantial information are bar talk … you have to calculate and present the impacts on weight, performance, and on the other criteria of a checklist … otherwise, you are taking decisions depending on whoever talks the loudest."

As shown in figure 10, the checklist is a rather straightforward index of questions mapping the impact of the proposed solution(s) on some key product development features. It includes regular project dimensions (e.g., cost and time) along with other characteristics which are central to the competitiveness of an aircraft, (e.g., performance and maintainability). At times there are some specific requirements of a particular aircraft, such as fleet commonality (these vary according to aircrafts and do not appear in figure 10). All these features represent general or 'integrative' objectives of product development (see Gerwin and Barrowman 2002: 940).

Figure 10. Checklist Technical Issues (reconstructed from field notes)

CHECKLIST		
Criteria	**Option X**	**Option Y**
Impact on Weight? How much?	...	...
Impact on Aircraft Performance? How Much?	...	...
Impact on Project Schedule? How much?	...	...
Impact on Recurring Costs? How Much?	...	...
Impact on Non Recurring Costs? How much?	...	...
Impact on Product Reliability?	...	...
Impact on Maintainability	...	...
Impact on Supplier Contracts?	...	...

The checklist influences the analytical work of experts in at least two ways. First, it encourages workers to put their local concerns to a side while considering the broader implications of the proposed solutions. This is important because a change in virtually any aircraft system may impact features such as maintainability or costs. Although dedicated experts oversee these variables (e.g., maintenance engineers), they cannot be present at all moments and in all technical meetings. Therefore, often these aspects may go unnoticed — and some of them are even treated as marginal for the product development (e.g., maintainability).

With the aim of counterbalancing the previous point, the checklist draws experts' attention towards these criteria. When technical issues compromise one of these variables (e.g., weight increase), presenters are required to offer justifications. This is the case even when the checklist is not overtly included in the presentation; the participants in the meetings may still refer to it as an objective reality which a specialist must deal with. For example, in a discussion about a proposed change in the material of a wing part, experts presented the customary supporting evidence. Half-way through it, the chief engineer noted he did not see "any considerations on maintainability" and asked whether such aspect had been forgotten. The chief product manager then explained that an impact would "probably" be minimal. Unsatisfied by this vague assessment, the chief engineer insisted that before reaching a decision, they should provide a clear picture of the new material reparability level (linked to maintainability) "as established in the checklist."

Second, another important contribution of the checklist is to provide a clear baseline for the assessment of competing solutions. It lists items that are both critical dimensions of the product development and (because of that) relevant for any technical proposal (e.g., costs). Hence, the checklist works as a common denominator which measures and analyzes multiple alternatives: the characteristics of each one of them appear side by side in the checklist making such comparisons more clear-cut (see Option X and Y in Figure 10). For example, facing a choice on different materials for an engine component, experts compared the impact on costs and performance of each proposal and decided according to the priorities of the project: the aircraft met performance requirements comfortably, yet struggled with costs, hence the decision was to privilege the cheapest design solution.

Meetings with Protocols to be Followed and Forms to Fill in

Technical meetings are meant to integrate the perspectives of a variety of specialists, with the aim of leading to decisions that are systemically sound. This, however, is not only an aspiration; there are a variety of bureaucratic mechanisms to ensure that experts take interdependencies and general objectives of the product development into account. This formalization counter-balances the overall emphasis on specialization which can be found across the company. While one may expect engineers and drafters to be 'naturally' concerned with the contributions of all relevant groups and balanced solutions, to rely on good intentions is a risky policy (or uncertain at best).

More specifically, the bureaucratic aspects of technical meetings shape collaborative dynamics both within and outside of them in at least two ways. First, formalization makes problem-solving and decision-making more predictable. Workers know what they are walking into when attending such meetings. Their participation is not judged based on the mere will of leaders (unlike the situation described in the opening vignette). There is a clear protocol which everyone is familiar with and which stresses that experts must attentively consider systemic matters in technical discussions. This is captured in the general guidelines and inscribed in routines, templates, and checklists which are quite diffused despite not being mandatory.

Second, with specific regard to templates and checklists, formalization enables the criteria for the assessment of technical solutions to be more explicit. These materials show workers what needs to be considered in relation to technical issues and helps them to organize information accordingly. Instead of dealing with vague procedures when preparing for presentations, there are cells which need to be filled in and questions to be answered — like in a form. Furthermore, during meetings, these materials 'remind' participants about the systemic aspects of a technical issue. Again, instead of norms written on documents or inside the heads of people, there is a slide on the screen showing whether impacted areas have been considered and so on. Even when not overtly present, templates and checklists still have a role to play: individuals may refer to an objective artifact (different from an abstract norm) when assessing whether interdependencies and some general criteria have been considered or not.

Zonal Analysis Meetings: Joint Reviews of Design Interfaces

The following section discusses zonal analysis meetings. Similar to the technical ones, the goal of these meetings is to encourage workers to shift from a specialist perspective to systemic level discussions. This takes place on a larger scale in such meetings as they involve representatives from most engineering and drafting technical competences. Bureaucratization is also more explicit here, as the participation of experts and their discussions are strongly regulated. I start by overviewing the meeting and its origins, and then I explore three of its bureaucratic aspects: the chairman's work in arbitrating disputes and safeguarding general project interests, the control of expert's attendance; and the use of action items to assign responsibilities. Then, I discuss how the routinized nature of these meetings provides workers with a sense of security and makes design interdependencies more tractable and governable.

From a Safety Method to Formal Meetings

The zonal analysis is rooted in zonal safety analysis, an important method in the aeronautical industry to perform safety assessments and demonstrate compliance with certification requirements (e.g., ARP4761). It establishes particular safety standards for different aircraft zones, as each single one is subject to unique hazards (see figure 11 for an illustration of aircraft zones). This leads to requirements on both the location of the components as well as their interfaces, which drafters must attend to when designing them. For example, engine bleed ducts (which have hot air) may not be placed below hydraulic equipment in case leaking fluid accumulates and causes a fire.

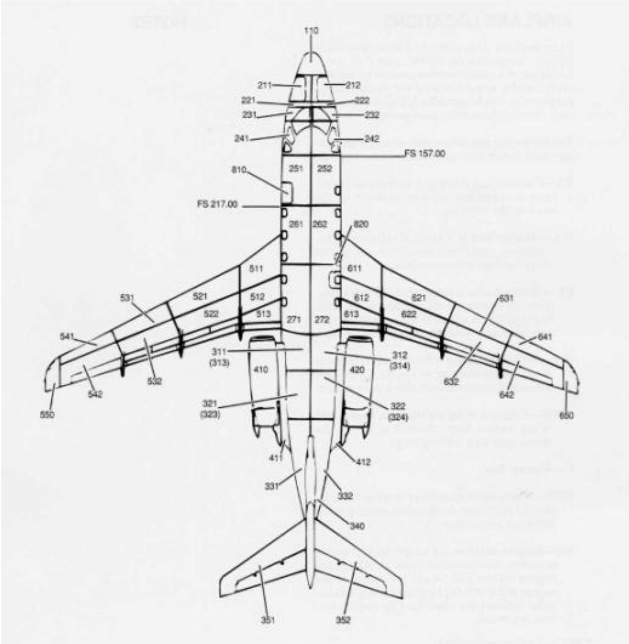
As explained in Chapter 4, dozens of drafters sketch aircraft parts at the same time in a digital mock-up. In contrast to this specialized work, zonal analysis standards demand experts to assess the design of components by means of a systemic perspective. PlaneCo workers square this circle by coming together in an event to go through design interdependencies: the zonal analysis meeting.

This kind of meeting is apparently unique to PlaneCo. It originated decades ago when a safety specialist translated the zonal safety analysis principles of the industry into a straightforward list of requirements. He then began convening a meeting with representatives from the main product engineering and drafting areas to review the compliance of aircraft designs with those requirements. The worker eventually retired but nevertheless the gathering remains a solid routine in PlaneCo, which brings together a vast and heterogeneous number of specialists (the sessions I attended had between two and three dozens of experts). Reflecting on its importance, a senior drafter said the following:

> It is easier to ignore, to not worry about the other [aircraft] systems on the computer screen, otherwise designing a part becomes much harder. Folks here pay attention to systems other than their own only when forced to do so, such as in the [zonal analysis] meeting, when they see the sub-system they designed interfacing with others … There, in front of everyone, they realize they need to deal with these other components and the experts responsible for them.

In this drafter's opinion, the zonal analysis meeting represents the opportunity for the experts to be confronted with the implications of their work for others. By doing so, it forces them to change gears, to drop their specialist perspective, and to deal with interconnections among systems designed by them and by other individuals.

Figure 11. Aircraft Zones (from DOT FAA AR-TN06 17 2006)



Analyzing Design Interdependencies in a Scripted Manner

Despite a somewhat casual origin, today the zonal analysis meeting has become the conventional way to bring together specialists when dealing with product design interdependencies. It is so established that it is taken as 'the' procedure for any situation when a systemic view on aircraft design is needed; a sort of recipe to make workers see beyond their specialist perspective. During my fieldwork, I observed many meetings with the 'zonal' title and with the related format. These included 'zonal' gatherings to assess design choices in commercial planes based on maintainability requirements; 'zonal' reunions to brainstorm on design problems involving many systems; and 'zonal' sessions to familiarize suppliers with all the systems in an aircraft section and the drafters behind them (suppliers do not have access to the entire digital mockup due to intellectual property restrictions).

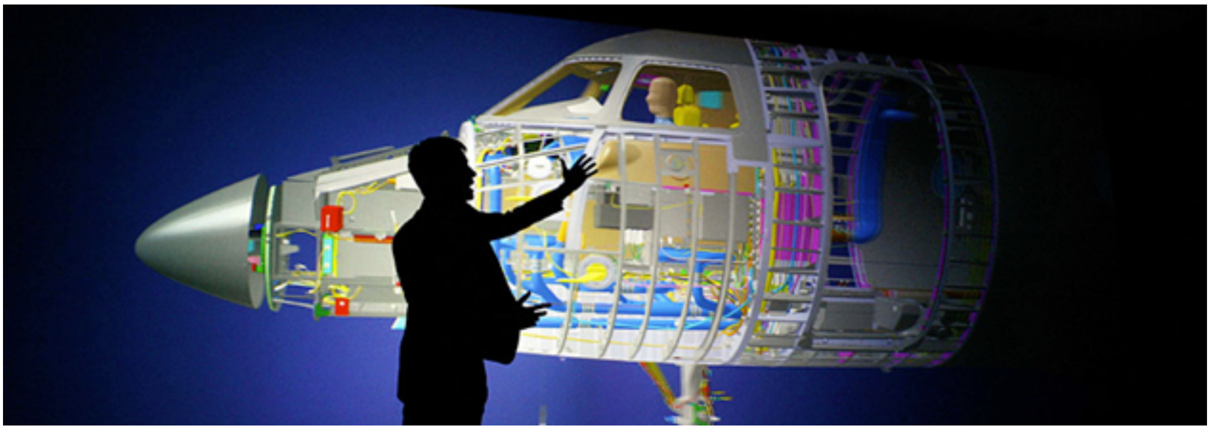
In all of these situations, meetings unfolded in ways which are comparable to the 'original' zonal ones. They were held in the same auditorium and according to an equivalent routine. The vignette below illustrates the structure and rhythm of these meetings:

> It is just before two o'clock when the chairman enters the large auditorium together with a safety engineer. A drafter is already sitting at the computer and loading the digital mock-up (see figure 12). The safety engineer opens a slide presentation and joins the convener at the front of the room. Drafters and engineers from various groups arrive and sit across the whole auditorium. By the time the meeting starts, there are more than twenty people present.
>
> The session begins with the convener explaining that today they will discuss the fuel tank area and asking the workers to sign the attendance sheet he circulates. The safety engineer then explains the particularities of this zone by using some slides. He asks whether employees remember some of the requirements, receives a mild level of engagement, and proceeds with the briefing.
>
> The chairman checks whether there are pending action items for this zone (there are none) and starts to review its multiple systems together with the audience. The assessment proceeds by sub-areas, considering the components and their interconnections according to the requirements.
>
> When issues demanding further study or re-arrangements between components come up, the drafter at the computer makes a screenshot of the area and roughly writes up the required actions — after the meeting, the chairman organizes them into action items which are then sent to the technical groups responsible for them.

The zonal analysis is the closest PlaneCo has to a moment in which representatives of all product engineering and drafting groups get together. As the vignette indicates, this happens in an orderly and routinized manner. The sensation is of being in a general assembly which unfolds in a scripted manner. There are weekly or bi-weekly zonal meetings for each plane throughout its development; they happen cyclically on the same day and time in an auditorium with a large screen showing the digital mock-up (see figure 12 below). There is a fixed rotating agenda for all meetings available on the project dashboard: each session focuses on an aircraft zone in a pre-set order (once all the zones have been examined the cycle re-starts). Attendance is compulsory and closely monitored.

The meeting progresses in a methodical fashion through a series of steps: a check on the previous action items, a briefing by a safety engineer, and most importantly the review of all the sub-areas in an aircraft zone vis-à-vis to requirements. A convener leads the process. The pace is one of a slow and steady activity, and the atmosphere is one of attentive problem-solving with experts pitching in with ideas (or whispering them to colleagues). Emerging issues are written down and screenshots from the digital mock-up are taken resulting in action items assigned via email to specific owners. On the next sections, I focus on the three building blocks of these routinized meetings.

Figure 12. Digital Mock-Up Showing Aircraft Systems (from industry publication)



The Convener: Arbitrating Disputes and Putting the Product First

All zonal analysis meetings have a convener, a role usually occupied by a senior worker. In those sessions reviewing safety and maintainability (which are the focus here), the convener is a senior drafter from the conceptual design department, also known in the company as the "zonal analysis guy." Conveners have a very active role: they chair sessions and make sure procedures are respected, and lead design assessment together with a safety or maintenance engineer. Of particular interest to cross-expertise dynamics is their arbitration responsibility. As a third party, they mediate discussions and have the power to settle arguments in light of what is considered optimal for the product development as a whole.

Disputes among experts in meetings are not rare. The most common source of arguments are those matters which involve various systems, and thus multiple experts. For example, when the distance among ducts and cables does not meet safety standards, there is the question of which one should change position. Because the re-arrangement of components generates extra work for those who are responsible for them, specialists wrestle to preserve the current configuration of 'their' systems. Similar to a heads-up, an engineer and key informant in fact told me the following before I started observing these meetings: "you will probably see different experts trying to push the work to each other … nobody likes to be the one to take the rap."

To ensure some fairness in these discussions — and that local interests do not get in the way of optimum designs — the convener elicits specialists to present their arguments for a given design alternative and decides accordingly. As he explained, "I give them the chance to speak and defend their case." Simple as this may be, it reduces the risk of prestigious experts monopolizing discussions and pushing decisions solely on the basis of their interests. Workers are expected to support their ideas based on technical justifications and to take into consideration the product in holistic terms (similar to what happens in technical meetings, as discussed above). The extract below serves as an illustration of this point:

> *Convener:* OK, let's look at the area around the engine pump now.
>
> *Structural Drafter:* Do you guys think we could place it further away from the APU [Auxiliary Power Unit]?
>
> *Fuel System Drafter:* Why? Is it a safety requirement?
>
> *Convener:* The current configuration is not ideal, right [safety engineer]?
>
> *Safety Engineer:* Here is the thing. The position depends on the rotor burst as in the related requirement … but we should also take into account the lessons we learnt from [an aircraft currently in operation].
>
> *Fuel System Drafter:* Well, the [aircraft in development from the same family] has 90 millimeters of distance, while here there is more even, 130 millimeters. So we are in a much better situation.
>
> *Convener:* This is not a good reason. We have more time to develop a better design solution … so we should not lose sight of what is best for the product!
>
> *Structural Drafter:* Also, we can take advantage of the extra space we have here.
>
> *Convener:* Right. I will open an action item with an observation that it is not a necessary change [but a desired improvement].

In this discussion, a structural drafter proposed to change the position of a component. As expected, the representative from the group which was responsible for it, the fuel system drafter, resisted. He claimed that the current configuration was already better than the one in a previous aircraft in the same family (airplanes in the same family share many commonalities). This justification was disputed. Structural drafters, together with the safety engineer, pushed this argument back by saying that the change reflected the lessons learnt from a previous project and that probably it was technically viable. Based on this information, the convener deemed the position of the fuel system drafter invalid and decided to create an action item requesting further studies and highlighting that the change was desired. Within this exchange, the convener had a major role in enabling all experts to present their position and in deciding on the best course of action for the product as a whole.

Attendance Control: Making Sure Meetings Are Representative

Having all experts in the same room is essential for a healthy collaboration. In the zonal analysis, the presence of workers from diverse areas is tightly controlled. Groups nominate representatives who must attend meetings according to the zones under discussion. Their presence is checked via signatures on an attendance sheet which has been prepared by the convener and is subsequently logged into an electronic system. Figure 13 provides an exemplary attendance sheet (a real one has dozens of rows); the cells in italics are the ones in which workers sign and add notes. It is important to highlight that the system has some inbuilt flexibility: specialists may also send a replacement on their behalf (see the examples of B and D).

Figure 13. Attendance Sheet for Zonal Analysis Meetings (recreated from field notes)

PLANE X – ZONAL ANALYSIS MEETING – DATE				
Name (as in email)	**Signature**	**Working Group**	**Contact Info**	**Notes**
Worker A	*Signature*	Structural Drafting	1234	
Worker B	*Signature*	Technical Support	1234	*On behalf of X*
Worker C	*Signature*	Avionics Engineering	1234	
Worker D	*Signature*	Air Management Systems Drafting	1234	*On behalf of Y*
Worker E	*Signature*	Safety Engineering	1234	
Worker F	*Signature*	Coordinator Wing	1234	

The presence of specialists is taken very seriously and assessed in a routine manner. This is probably why some seemed to be slightly incredulous, unaware at first of my research status, when seeing me taking and passing along the attendance sheet without signing it. Representativeness, i.e. the attendance rate of delegates from functional groups, is an official performance indicator of the zonal analysis. Project dashboards include graphs which measure it and are occasionally presented by the convener in project meetings and at the beginning of some zonal analysis sessions. The expectation is that such visibility will (gently) push leaders and peers to become aware of the absence of some specialists and take consequent action.

In practice, however, the tactic has limited success. Although leaders recognize the importance of having representatives in the forum, they argue that they need to balance this participation with the internal workload of groups. Hence, the convener finds himself lobbying for participation, asking coordinators to 'remind' supervisors and managers of the importance of attendance, and sometimes naming and shaming them. Consider what happened during a design review:

> *Zonal Analysis Convener:* So this is the situation [points to a slide showing frequency charts with attendance levels of all areas]. I am starting to get concerned, this phase began OK, but now we are missing many representatives…
>
> *Chief Product Manager:* [in a heated tone] This is unacceptable … some groups seem to be absent in more than half of the meetings!
>
> *Zonal Analysis Convener:* Yes, as you can see, flight controls, drafting and manufacturing engineering have only been present in 40% of the gatherings.
>
> [Discussion unfolds on the reasons behind the absences; this include mistakes in the nomination of representatives and project deadlines. The chief product manager demands that all areas clarify who are their representatives and adds the following plea].
>
> *Chief Product Manager:* Let me be clear, the zonal analysis is very beneficial for us … but we can only reap the benefits with the participation of all areas!

In this exchange, the convener showed the representativeness indicator to senior leaders, including the chief product manager. It displayed which groups were the most absent, leading to a debate on the reasons behind the problem (e.g., groups nominating too many representatives) and a reminder of the importance of attendance. After this discussion, I walked with the chief product manager and I observed that the convener came up to him to thank him explicitly for "insisting on the importance of [high levels of] presence."

Action Items: Assigning and Documenting Work

There is a clear policy to allocate the work which results from the problems discovered in the zonal analysis meeting. When issues cannot be dealt with during these meetings, usually because they require further calculations or redesigns, action items are created and the convener takes care of their assignment. Ownership invariably falls on an individual/group — even when an issue is of interdependent nature. This is why the struggles described above are so noticeable: discussing what ought to be done is invariably linked to who will be ultimately responsible for it. However, re-arrangements do happen. Groups members shuffle tasks related to an action item and ownership can be shifted across groups pending on their mutual agreement.

All action items are detailed and visible in a database. As work towards them unfolds, progress is updated and details about the methods and the analysis employed are also documented. As the convener puts it, "announcing that the issue is solved just because their boss said so does not cut it." Similar to attendance control, there is also a performance indicator for the action items which highlights the progress made (e.g., how many are overdue, which groups hold the most delays, etc.). All this information is also available on the project dashboard. However, unlike the case of representativeness, this indicator is taken very seriously. As a matter of fact, it represents a requirement for design reviews.

The action item system echoes an overall attention for individualized responsibilities in the company (see Chapter 4). On the upside, it enables PlaneCo to accurately govern activities that may depend on cycles of interactions among employees. Also, they serve as records of technical problems and of their resolution, by registering discussions, analyses, assessments and so on. This is quite helpful because all of this information may serve to justify design choices to certification bodies.

On the other hand, however, the insistence on individual ownership sometimes creates tensions, especially when specialists resist being assigned responsibility for issues that depend on the contributions from many experts. The following interaction between the convener and a representative from the environmental control system drafting group illustrates this point:

> *Convener:* So, you guys [environmental control system drafters] will be responsible for evaluating this issue.
>
> *Environmental control system drafter:* [interrupts] Wait a moment! The [environmental control system engineers] should be the ones doing it, as it requires first an analysis on the functional aspects of these components…
>
> *Convener:* Yes … but eventually, the goal is to re-define the physical interface of the system, which as you know is a drafting responsibility. So I will open the action item for you guys and you can then sort it out with them.

The convener assigned the responsibility to a drafter, despite the protests. After the meeting, I approached him to ask about the reasons behind his decision. He was of the opinion that responsibilities should fall on a single person/group and that ultimately drafters, and not engineers, are accountable for the physical interfaces of a component (even though they depend on inputs from engineers).

The convener also added that he does not worry too much over which group to assign the action items to. If it is a reciprocal process, experts will have to work together anyway (environmental control engineers and drafters define the design of a system together). In his view, the action item is 'simply' a way to have someone responsible for kicking off the (joint) work. The line of reasoning is simple and reflects the idea that if everyone is responsible, nobody is. Assigning collective responsibility for tasks poses the risk of creating a situation in which each part expects the other to start/accomplish the activity (this is further explored in the discussion chapter). As a chief product manager said to his team, "the rule here is to assign action items to a single group or person, this way we know that someone will 'feel the heat' to get on with it."

Coming Together Via a Routinized Process

Zonal analysis meetings are essential to tackle product design interdependencies and encourage specialists to go beyond their particular perspectives. They may well have started as sessions run according to the vision of a charismatic engineer, but today they follow a routinized process. Zonal analysis meetings have become quasi-ritualistic: experts congregate in the same place at pre-set times and days, they discuss themes stipulated on a cyclical agenda, and they abide by the controls enforced by a convener. They represent so much of a 'meeting format' that employees across the company make use of them as a routine to deal with design interface issues (see examples above).

While technical meetings present protocols which set a general conduct for the discussions, zonal analysis ones are slightly more bureaucratic and include a tighter regulation of experts' participation and of their relations. There are three main implications of running these meetings in such a manner. First, a routinized process provides a sense of security. Zonal analysis meetings are a familiar element in a universe as fraught with surprises as aeronautical product development. In particular, it makes dealing with intricate design interfaces more of a structured affair. Leaders and workers know that in every aircraft project there is a place, time and way to attend to design interfaces and that a single point of contact is watching over the process.

Second, and related to the previous point, routinization makes design interdependencies more tractable. To have a dedicated process relieves experts of the cognitive burden of deciding how to deal with intricate design issues by themselves because there is an organizational 'recipe' to rely upon. They have a definite routine and a structured way of going about design interfaces. This limits the complexity of the overall task. Doing it in a more open-ended session would probably be further daunting (the risk would be of going in all directions and remaining overwhelmed by the intricacies of aircraft design).

Third, a routinized process also makes it all the more governable. A formal process is by definition given by a series of steps which need to be followed; in fact, zonal meetings happen in a disciplined manner with participants playing established roles (e.g., convener, representative). Besides this, a process provides a baseline of what should happen and make it easier to check that it actually does. For example, it makes it possible to record, monitor and construct metrics to control participation. Interestingly, this is a stricter solution for a problem that also haunts technical meetings (i.e. the presence of the appropriate individuals). Finally, the governance of a formal process can be entrusted to an owner who is expected to direct it according to procedures (instead of merely based on one's personal will).

Configuration Meetings: The Center of the Product Change Workflow

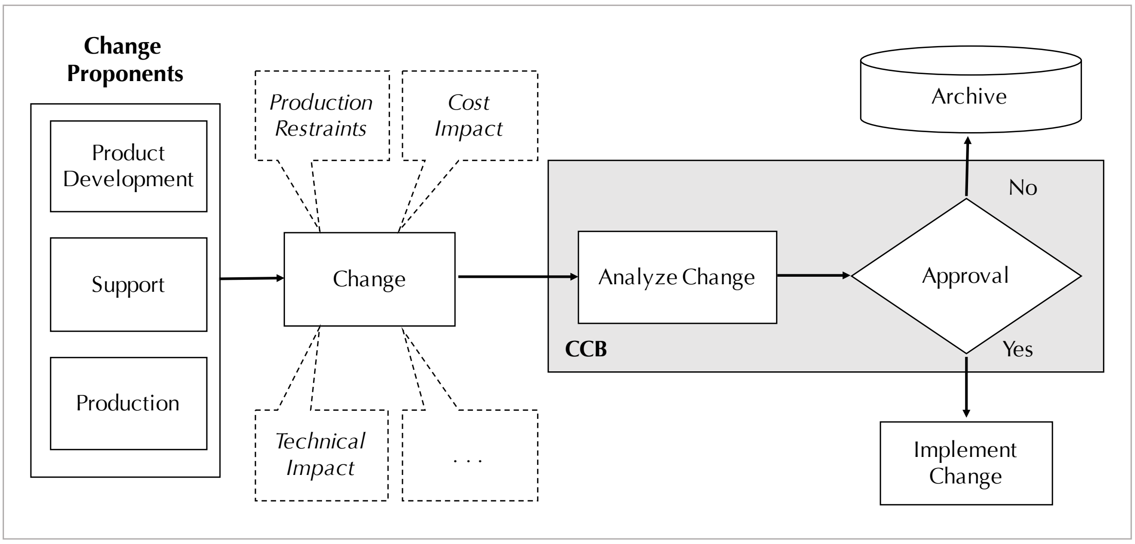
In this section, I explore configuration control meetings. Organized by configuration control boards (CCB), they represent a checkpoint in the product change workflow. Among other requirements, in them, these boards examine whether all areas that are impacted by a change are in sync — they also promote integration among parts, yet this is a slightly incidental feature. While reminiscent of technical and zonal meetings, the jurisdiction of configuration meetings goes beyond the engineering unit and their focus lies on the implementation of technical solutions (and not just their discussion). Below I outline the change process, the boards, and the meetings. Subsequently, I explore the work of CCBs which inspect and facilitate the alignment among experts and discuss how their central position in the change process enables them to gain a comprehensive view over design change matters and a solid relational capital — which are both crucial for their work.

Changes, Boards, and Meetings

Configuration control is a method used to manage modifications in a product throughout its lifecycle. Common in many industries, it is of particular importance in aerospace. The overall aim is to maintain product integrity, i.e., making sure technical changes are thoroughly documented and do not compromise the functioning of the product. In general, changes follow a formal (and lengthy) workflow. Here, I am interested in the portion which falls within the remit of configuration control boards; more specifically, the reviews they carry out in CCB meetings. Figure 14 shows the configuration control workflow in a schematic manner in light of the present focus.

Changes have many sources (e.g. defects, improvements, customizations). Because the modification of a component may 'reverberate' on others, as well as on the manufacturing processes and the supply chain, workers must assess its impact on the various aspects of the product development (e.g. design interfaces, supplier contracts, production capacity). In PlaneCo, this means contacting specialists from many groups to gather the necessary information and check their agreement and potential demands — workers refer to this as "aligning specialists" or achieving "integrated proposals" (similar to what happens in technical meetings). For example, the change of a simple carpet in an executive jet, one of the many I observed, required the go-ahead of the aircraft interior specialists, assessments by safety engineers on the flammability of the new component, and a list of suitable suppliers from procurement analysts, among others.

Figure 14. Configuration Control Workflow (reconstructed from field notes)



Once a change and its impacts are appropriately detailed, it is then submitted to a configuration control board (each aircraft, or group of them, has its own board). They analyze it and assess it. CCBs are created once the drawings are released to production and remain active throughout an aircraft's life service (which may last for more than 30 years). A chairman, and a member of the program management group are at the head of the board which also includes representatives from procurement, production planning, and manufacturing engineering. They work full-time as a cross-functional team and sit adjacently. Others join in when needed (e.g. configuration control analysts).

After checking whether a change meets the criteria, the board schedules a time slot for its presentation in the CCB meeting. During these sessions, workers 'defend' a change proposal as the board members check that it complies with the requirements (including the one about the involvement of appropriate experts). Meetings have a vivacious nature, quite different from the more academic tone of the technical and zonal ones. When I attended these meetings, I felt as if I were in the front-office of a public service with people waiting to get some sort of authorization. There are individuals sitting/standing who appear to be mildly bored, pacing in and out, and checking their phones while employees review cases according to fixed criteria.

Were I not familiar with the intricacies of aeronautical product development, the CCB meeting could appear to be a rubber stamping exercise. But that was not the case. The history of aeronautics is fraught with misfortunes caused by design changes lacking documentation or escaping the attention of relevant experts (see chapter 3 in Johnson 2006). Furthermore, CCBs share the sense of urgency of PlaneCo (see Chapter 4). Even though they are severe about the need to follow norms, they are equally stern about approving important changes promptly. In the words of a CCB chairman, "we are a necessary evil, costly for the company … so we do all we can to make it as reliable and quick as possible." Indeed, meetings are in principle a swift, in-and-out chat. People come in for a couple of minutes, present some technical sketches, answer questions and it is done. Yet, when change proponents do not do their part, the situation is much more complicated (as will be discussed in greater detail in the following sections).

Inspecting The Alignment of Expert Groups

CCBs can be seen as the custodians of the change process. They make sure that all groups that are impacted by a modification have been informed and that their concerns are adequately represented (a feature which echoes technical meetings). As explained by a CCB member, the goal is to "check that everyone is in the loop and in agreement." Indeed, while spending time with board members, I often heard them debate whether a change was "well-aligned" or not. This leads CCBs to consider, for example, if a supplier confirmed a stipulated delivery deadline or whether manufacturing representatives agree with the suggested date to incorporate a change in production (known as its 'effectivity').

It is also not uncommon for CCBs to delve into the technical details of the product development (a gray area with regard to their jurisdiction), unpacking the changes to check whether the opinion of certain engineering groups is missing and demanding that further technical information be gathered/clarified. As an illustration, consider what a CCB member said to a drafter during a discussion about a change in a wing part:

> If there is a chance, however small this may be, that this impacts the tolerance levels [permissible variation limits in the dimension of a component], we need to hear from the GD&T folks [Geometric Dimensioning and Tolerancing] even if this is a design solution already used in [a previous aircraft].

The drafter implied that the change would entail a lowering of the tolerance levels, arguing that this was acceptable since a similar solution had been implemented in a previous aircraft. The CCB chairman, however, was adamant; he insisted that approval from the experts on engineering tolerances was required.

The meticulous concern towards ensuring that all important specialists are 'in alignment' is of particular importance when facing time pressures. CCBs do go above and beyond to deal with urgent requests (as discussed later). However, they are also careful not to abandon their mandates. This leads to tensions as they push back changes, reschedule them, or demand clarifications.

For example, with regard to the modification of a wing component, for which there was some haste, the CCB members asked the proponent whether he had considered the opinion of aerodynamics experts on the possible impact of the new component on drag (the friction with air which reduces speed and increases fuel consumption in planes). He admitted to "not knowing": specialists had not been consulted as he thought the impact would be minimal. To that, a board member retorted, "we *have to* know that sort of stuff" and demanded the worker to get in touch with someone from the aerodynamics group.

Besides making sure specialists are consulted, CCBs struggle to get change proponents to see issues from someone else's perspective, i.e. beyond their own specialized view (here the parallel with technical meetings is evident). This happens even in the simplest of situations. A case in point took place during an apparently straightforward change, i.e., altering the assembly line station in which a component is installed. The proponents saw it as a rather insignificant alteration: the part would not actually undergo any 'real' modifications, thus they expected approval to be given on the spot. But the CCB chairman had reasonable concerns and invited them to step back and walk in the shoes of production groups:

Change Proponent: Today the installation is done in [a hangar]. But doing it [in another] would be more appropriate [for some technical reasons].

CCB Chairman: OK, I understand that technically the change is sound. But doing the installation in [a different hangar] raises the issue of resources.

Change Proponent: Well, it is all under the same director ... plus the installation of the component will most likely be done by the same folks who do it now.

CCB Chairman: Look, we do not know that … I am not sure how the planning of the [manufacturing director] is structured. Do you? It might create disruption!

In this dialogue, the workers argued that the impact of the change was minimum and that it would make the process more efficient and effective given some technical requirements. Nevertheless, the chairman continued to push back, saying that they should not make assumptions about the work in the production line if they did not know it in detail. He insisted on the need of getting more inputs from the production group which was responsible for the installation of that particular component before granting any approval.

From Inspecting to Assisting Alignment

If all changes requests followed the change procedure dutifully — contacting experts and reaching agreements beforehand — ideally the CCBs would then just have to ratify the arrangements and manage the change implementation. This, however, is not the case in reality. As a CCB member explained, "sometimes the changes presented do not add up … relevant experts have been ignored; agreements are inexistent, it is all disjointed." In principle, the CCB could reject these proposals. But occasionally they take a proactive role and help change proponents measure up to procedures. Interestingly, different CCBs had diverse stances on this matter: some only check while others also promote integration. When CCB members assist alignment, they do this by helping experts to contact each other, and by taking up the responsibility themselves for the integration of all those involved in a change.

Facilitating Contact Among the Experts (Who Should Be) Involved in a Change

When sitting by the CCB office, I had the chance to observe the fact that all kinds of workers arrived in search of assistance. As a matter of fact, confusion about which experts to contact and how to reach them is quite common in PlaneCo. Thus, the most basic way in which CCB members provide help is by supporting change proponents to reach the groups which are relevant for a given modification. Like a helpdesk, the CCBs give instructions on who to reach out to about what. Often this happens in the midst of meetings. In virtually all of the dozens of CCB sessions I observed, there was at least one call to representatives from groups to inform them about a change proposal, discuss its implications, or seek an agreement. For example, in a situation in which a change proponent was unsure about some details, the chairman contacted a configuration expert for him:

> *Change Proponent:* So, I am not sure what to do regarding the [implementation date] of the change. Can we include a plane which is about to be delivered?
>
> *CCB Chairman:* Yes, but not like that ... Let's ask the configuration managers.
>
> [Calls and speaks on speakerphone] Hi … is X there?
>
> *Configuration Manager* [on speakerphone]: No, he is out of the company today.
>
> *CCB Chairman:* [on speakerphone] What about Y? Can you give me his number?
>
> [The chairman gets Y's number, calls, and explains the situation; he then asks him to come to the meeting right away. In five minutes Y is there to clarify the matter.]

The CCB chairman swiftly contacted experts who could provide the information that the change proponent needed. While this only took the CCB chairman some minutes, since he knew to whom to speak, the same task might have required a lot of searching by a worker with limited familiarity with the configuration management group.

The CCBs' ability to help workers reach others stems from their hub position: people from all over the company are linked to design changes, in one way or another. During an interview, a CCB chairman mentioned that after assuming the position he "started speaking with areas [he] did not even know existed." He then showed a contact list which had been put together during the past year and which comprised the representatives from almost all key departments in PlaneCo. I, myself, also exploited the social capital of CCB members on various occasions; many times, I asked for their support to contact new interviewees. Unsurprisingly, they almost never failed to put me in touch with representatives from a variety of groups.

Besides being a helpdesk or a living telephone switchboard, CCB members also facilitate contacts by allowing CCB meetings to turn into 'meeting points', despite being in principle only aimed at reviewing proposals. In other words, they became an occasion for working out agreements, instead of approving them. Because this event brings people from all over PlaneCo together, it is clearly conducive for encounters. For this reason, change proponents make use of it to meet face to face and talk through issues. This habit was reasonably diffused even though CCB members were not entirely pleased with it, as they would much rather have workers arriving prepared to the meetings.

Brokering Alignment for Changes on Behalf of the Workers

CCBs also act as brokers or intermediaries for changes — a role which is more frequent in critical moments. Instead of only putting people in contact with each other, they take a change request into their own hands and coordinate the alignment with all the impacted groups. They ring people up, secure compromises and even call in favors. A case in point was given by a change in an air duct which required a certain urgency. A chairman took a proactive position, sorting out the outstanding issues and pulling all the areas together, as illustrated below:

> *Configuration Manager:* I was expecting this change to happen much later…
>
> *CCB Chairman:* I know, but it is a priority … you know me, I would not ask if this was not important [configuration managers nods her head in agreement].
>
> [The chairman calls a manufacturing engineer via the speakerphone, explains the situation, and asks whether he can meet the proposed timeline].
>
> *Manufacturing Engineer:* [on speakerphone] Yes, but we are waiting for the drawings.
>
> *CCB Chairman:* [talking on speakerphone] Wait, hold on a minute. [looks at a drafter in the room] Could you guys release the drawings earlier?
>
> *Drafter:* Yes, we can.
>
> *Manufacturing Engineer:* [on speakerphone] OK.
>
> *Chairman:* Great, we are all in sync then!

The CCB chairman aligned different areas to make a change possible within a tight timeframe. He got a configuration manager to agree on an earlier date and sorted through the interdependencies between manufacturing engineers and drafters on the fly. As he explained to me after the meeting, there was no time to wait for the change proponents to contact and negotiate with all these groups (an important client had requested a last minute modification in an executive jet). Hence, building on his understanding of the change process and his familiarity with the various groups, he worked to get all the parties in sync.

At the extreme of this brokering work, CCBs may go as far as bending norms. This is most common in situations in which the agreement among workers is solid, yet corporate systems delay the process. In another time sensitive change regarding an aircraft carpet, the engineer leading it explained that the drawings and the related documentation were all ready and that the manufacturing groups were set to incorporate it. The problem was that the information on it would not arrive for production within a certain timeframe due to the update routine of the manufacturing planning software. This is what happened during the meeting:

> *Change Proponent:* All is on track. Drawings have been released … and we need to incorporate the change in plane X [entering production].
>
> *Drafter:* But the manufacturing planning system will no longer update today.
>
> *CCB Chairman:* Let me understand, manufacturing is OK with the change? Is the software update the only problem?
>
> *Manufacturing Engineer:* Yes … we have to sort this out soon, before [some related components] are installed in the production.
>
> [as the discussion unfolds, the overall agreement is that this change is critical and making the manufacturing system do a forced update would be too complicated].
>
> *CCB Chairman:* Well, my concern is that we need to be very clear with the groups doing the installation … they would need to check that the new part is incorporated practically by hand [i.e., without information being available in the system].

Paradoxically, in this situation, the workers were all in alignment. But the software system did not allow them to honor their agreement and introduce the change in a plane entering final assembly (in which incorporating the modification was important). Since running a forced update of the system was tricky, they eventually took a 'detour' from the norms with the 'blessing' of the CCB. They informed the production groups about the issue and these agreed to implement the change before it was visible in the system. This example illustrates how a CCB bent some norms (which would require abiding by the software update routines) while maintaining the overall purpose behind them, that is, making sure that all parts involved in a change are in sync.

A Centralized Authority to Assess/Promote Integration

Similar to technical and zonal analysis meetings, configuration control ones are organized to ensure the involvement of experts in systemic matters. The strategy here is not to monitor discussions according to protocols or to regulate attendance via control mechanisms. Instead, they are set to review whether exchanges and interactions among experts have already taken place. The process is led by configuration control boards: the authority centralizing the approval of change proposals and auditing whether and to what extent all relevant areas stand behind them or not. Interestingly, boards also demonstrate a very proactive behavior, by facilitating the integration among experts around changes as much as by inspecting them. This centralization in the hands of boards of a process spanning company areas has two important implications.

First, centralization gives CCBs a comprehensive view when assessing the alignment of areas around changes. As a fixed and small group dealing with a variety of issues/individuals on a daily basis, they eventually develop familiarity with and a sympathetic understanding of different experts. This qualifies CCBs to inspect the changes in meetings in a holistic manner: they are more likely to balance the demands of various groups optimally and spot ripple effects which specialists might be unaware of (see, e.g., vignette above on page 131 on a change in the installation hangar of a component). This is reminiscent of technical meetings; yet here, this activity is not accomplished collegially (with the aid of soft control mechanisms) but carried out by appointed individuals (CCB members).

Second, centralization provides the relational capital which enables the CCB to assist experts getting in sync around a change. The CCB includes representatives from key company areas. In addition, since it is a convergence point which all those proposing a change must pass through, the boards develop further ties with a variety of experts (just consider the enviable contact list of a CCB chairman, as described above). Thus, they can easily put individuals in touch and call in favors with peers when needed to put changes forward (see the vignette, on page 133, in which a CCB chairman resorts to his network).

Conclusion

This chapter illustrated the cases of experts dealing with systemic interdependencies (summary in Table 5). They highlight, for example, the challenge of incorporating inputs from various specialists and aligning them behind technical issues, design proposals, or product changes. Typical to the aeronautical context, these dynamics are also key to cross-expertise collaboration in general; in fact, many studies explore the efforts around integrating the contributions of different professionals (Majchrzak et al. 2012) and working their — possibly conflicting — demands together (Carlile 2002).

The chapter also showed how much bureaucracy underpins these processes. In particular, it examined how formalization, routinization, centralization and related rationalization apparatuses reduce the uncertainty in the way workers prepare for and interact in and around meetings, among others. These bureaucratic mechanisms establish which information is required in discussions (e.g., systemic considerations in technical meetings); what kind of matters are addressed when, by whom and how (e.g. design interfaces in zonal analysis); and what are the norms and criteria according to which ideas and proposals are reviewed (e.g., alignment in design changes).

While organizational scholarship primarily focuses on emergent, informal and communitarian aspects of meetings, this chapter showed how much bureaucracy may be intermeshed with them. Thus, to speak of meetings without paying attention to procedures, roles, norms and similar formal elements is analytically incomplete. The two things are not mutually exclusive, however. As discussed in the previous sections, experts may come together according to control mechanisms, under the guidance of a particular leader, or due to a set of precise criteria and requirements. In short, meetings can be bureaucratic. And this might be essential to enable an adequate participation of experts, systemic discussions, and the integration of various perspectives into a common solution.

Table 5. Summary Cross-Domain Meetings

	Technical Meetings	***Zonal Analysis***	***Configuration Control***
Main Purpose	Discuss technical issues and decide on competing solutions	Review product design according to certification requirements	Review and coordinate design changes in the product
Experts	Experts from all levels of seniority (including technical fellows) and leaders from groups and departments	Convener, assistant, senior safety engineer and representatives from all specialist areas in engineering unit (drafters and engineers)	Configuration Board (Chairman, Manufacturing Engineer, Production Planning, and Procurement Specialists) and representatives of engineering unit and beyond
Bureaucracy	Technical problem-solving abides by norms uphold by leaders and peers and inscribed into templates and checklists	Experts come together to discuss product design according to a routinized process, and there are formal control mechanisms governing it all	A committee oversees the design change process and establishes a checkpoint to review change proposals

CHAPTER 6

KNOWLEDGE EXCHANGE TOOLS

HOW BUREAUCRACY FORMALIZES THE CIRCULATION OF INFORMATION AMONG EXPERTS

Carl Hammoud – Analepsis (Flashback)

Introduction: Knowledge Exchanges in Black and White

> *One morning while in the field, I took a taxi to PlaneCo. As soon as I boarded it, the driver said that he knew the company well. He had worked there for thirteen years but had left a decade ago. After enquiring about the purpose of my visit, he shared some impressions of his time in the production floor. I was surprised to hear that he was glad to have left; he said that he enjoyed the flexibility of establishing his working hours, "now if I need to take my kids somewhere or go to the doctor, I just do it." He complained that the work in PlaneCo was very stressful with so many tight deadlines. And the worst part, according to him, was the miscommunication among departments. "My supervisor would reset production, throwing away boxes of parts already manufactured, after being informed too late about a design change … or simply receive demands that something had to be done by tomorrow at the last minute." He then added that he felt information would never arrive at the right time and concluded his rant reiterating that he did not know how are things now in PlaneCo, but that back then information exchanges across areas were a messy business.*

Exchanging knowledge is a central aspect of cross-expertise collaboration. To work together effectively and build upon shared ideas, experts must circulate information appropriately. In PlaneCo, virtually all specialist groups provide inputs and outputs to each other. Thus, as reported in the story above on the tribulations of an ex-production employee, communication breakdowns may cause considerable turmoil in the work process and strain among individuals. Because of them, experts miss deadlines due to incomplete or delayed information and managers handle interfaces poorly since they lack a clear vision of the knowledge flows across groups.

In the past, these shortcomings were common as exchanges unfolded in an erratic manner. In fact, the account provided by the ex-employee is quite similar to many I collected from PlaneCo veterans. However, throughout the years the company implemented several bureaucratic tools to make information flows more ordered and manageable; today specialists in the company have at their disposal formal channels to request and share information.

These tools record details about exchanges and make experts liable for possible agreement breaches. Using a metaphor, we may say that they put details about exchanges in black and white — very much as though they were modern economic/legal transactions. The characteristics of these tools and their impact on the relations among specialist groups in PlaneCo is the focus of the present chapter.

The literature on cross-expertise collaboration usually views bureaucratic apparatuses as an impediment for knowledge sharing, while at the same time extolling the importance of interpersonal factors (Hansen 2002, 1999, Kotlarsky and Oshri 2005, Swart and Kinnie 2003, Wang, S. and Noe 2010). A minority of studies based on an information processing approach focus on the role of formal organizational elements (e.g., matrix structures, liaison roles). However, they only look at how organizations may transmit (more) information at lower costs without discussing the extent to which transfers are formalized and governed (i.e., bureaucratized) (Galbraith 1977, 1974, Tushman 1979, Tushman and Nadler 1978, Tushman 1977). Similarly, the few studies on knowledge sharing systems and bureaucratization only focus on the ways in which formalized systems serve as control mechanisms to discipline (individual) professional work, while ignoring any possible role they may play in the regulation of exchanges among experts (Brivot 2011).

In order to address this oversight in the extant scholarship, in this chapter I explore three tools which formalize knowledge exchanges among specific expert groups in PlaneCo. Unlike the cases examined previously, these bureaucratic arrangements are very much local creations and particular to the universe of this company. I present them according to a decrescendo: from a situation in which formalization is very evident to one in which it confounds itself with common elements of product development work.

First, I concentrate on a tool I call "knowledge sharing registry" (an alias I use to preserve anonymity). The registry is a database recording information requests among expert groups in the engineering unit and represents a bureaucratic adaptation of a method known as Design Structure Matrix (DSM). The fact that the details of agreements on information exchanges are written down in the registry and enforced routinely by a third-party (i.e., product management teams) suggests the bureaucratic dimension of such a tool.

Second, I examine the "information collector" (another pseudonym), a tool used by drafters to request information from engineers regarding technical drawings. This represents a formalization of a routine interaction in PlaneCo (drafters design aircraft components according to engineers' specifications) and echoes the previous case. Bureaucracy here is also interlinked to the recording and control of exchanges, albeit it happens in a more automatic manner: information requests are logged directly in the product design system and have a specific timeline attached to them.

Third, I explore "communication standards" (an alias as well) which formalize the transmission of information between the two main drafting groups in the company. These enable mechanical and electrical drafters to pass information to airframe drafters about aircraft components. Bureaucracy is present here too, albeit more lightly: experts inscribe information into drawings using a system of design conventions.

In the next sections I review each case separately, by considering their characteristics, the collaborative dynamics they illustrate, and the role of bureaucracy supporting them. At the end of the chapter, I offer some general conclusions.

The Knowledge Sharing Registry: When Experts Write Down Agreements About Information Requests

In this section, I explore a formal system to record and control information exchanges at a fine-grain level. I have labelled it the "knowledge sharing registry" to stress the importance employees attach to the agreement logged in it. I first explore its origins and characteristics and then I present how it works in practice. Next, I show how it enables coordinators to check that information is requested/delivered in an appropriate manner and to deal with interdependencies among specialists, thus preventing systemic problems from arising. In closing, I review how the formalization that stems from writing down details about exchanges gives them an official and binding dimension and makes controlling exchanges easier.

An Interdependence Matrix Becomes a Registry

Vast amounts of information circulate across the groups involved in the product development. As discussed in Chapter 4 (see "cycles of information exchanges"), creating an aircraft part takes a whole village of specialists exchanging dozens of documents, calculation results, and technical drawings — what employees call "inputs/outputs." These transfers are so constant and minute that they are not part of the official project planning. Product development schedules only show major deliverables, which, however, depend on the information that comes from a handful of groups in a cascade. For example, CAD drawings, created by drafters, hinge on the inputs of structural engineers who in turn depend on the calculations made by the loads and aeroelasticity group. CAD drawings, in turn, are inputs for manufacturing engineers and technical publication specialists.

Exchanges at such a granular level have traditionally been handled by experts informally on a one-to-one basis. However, as the company started developing various planes in parallel — and as the popularity of project management and system engineering ideas took hold — initiatives were put in place to manage knowledge exchanges in a more structured manner. Program and product managers started searching for tactics to organize knowledge flows across specialist groups to ensure that the required information would change hands in a timely manner. To this end, more or less a decade ago, a decisive tool to map and monitor exchanges was developed: the knowledge sharing registry.

The registry started as the application of a method known as Design Structure Matrix (DSM) to map interfaces in complex product development (Browning, T. R. 2001, 2002, Eppinger and Browning, T. R. 2012). A chief product manager (who eventually became a director in the engineering unit) had read some literature on systems engineering and on the DSM and he convinced peers to experiment with it. Traditionally, a DSM is used to manage interfaces in complex environments as it enables the modeling, visualization, and analysis of interdependencies among the components of a system. It is shaped as a square matrix with rows and columns mapping interrelationships with different elements, such as tasks, physical parts, or organization subunits (see Figure 14).

The implementation of the DSM in PlaneCo was at first very faithful to the original. The matrix was filled with the names of the groups and it was used to specify the information requests among them. By reading the intersections between rows and columns, one would be able to find the inputs that experts require from one another. For example, as illustrated in the first row of the DSM below (Figure 15), 'B' is asked to provide information to A and C. Although this rapidly became the ultimate tool to record information requests across groups, it started to take on a very local flavor during the process by incorporating local traditions and becoming increasingly 'bureaucratized.'

Today, the matrix has made way for a general spreadsheet (see Figure 16 for an illustration). In this new format, rows display information requests; columns feature details about the request, requester, 'supplier,' proposed due date, agreed due date, current status (e.g., planned, delayed, done), and space for any comments, used to record any re-planned agreements or other kinds of notes. The spreadsheet resembles a traditional project tracking spreadsheet (comparable ones are used in PlaneCo for task management monitoring).

The spreadsheet maintains the capacity of a DSM to highlight co-dependencies among elements — expert groups in this case — while fitting the PlaneCo universe. Two new characteristics are noteworthy of attention. First, the spreadsheet lists the names of workers as requesters. Groups are sometimes split into sub-specializations which means that a specialist's name is a more accurate choice (e.g., as the name suggests, the loads and aeroelasticity group includes two distinctive expertise areas). Also, the use of personal names fits the company's attention towards individual responsibility (see Chapter 4). Second, the spreadsheet features two due dates. This is because deadlines are typically the source of dispute; therefore, to smooth strain among experts, both the date originally proposed by the requester and the one agreed after negotiations are recorded.

Overall the system shows who requested information from who, the demanded and agreed upon due dates, and the status of the exchange. Although demands for information may arise at any time, most requests are made after the work schedules of a development phase are established. Functional leaders and senior workers record these requests according to the deadlines of the key deliverables of their groups. The convention is that specialists contact the person/group which they are requesting information from; once they reach an agreement, it is recorded onto the spreadsheet by a member of the product management team (usually only one person has editing permission). The database is visible on the project dashboard to everyone.

Figure 15. Exemplary DSM adapted from the Literature (from Browning, T. R. 2001)

	Element A	Element B	Element C
Element A			
Element B	X		W
Element C	Y	Z	

Figure 16. Knowledge Sharing Registry Spreadsheet (recreated from field notes)

Number	Description Item	Requester	Supplier	Proposed Due Date	Agreed Due Date	Status	Comments
1	Finite Elements Model Flap	[Loads Senior Specialist]	[Structural Engineering Supervisor]	01/05/15	01/06/15	Delayed	Expected since one week ago
2	Engine Dynamic Model	[Aero-dynamics Engineering Supervisor]	[Engine Engineering Specialist]	05/06/15	05/06/15	Planned	[blank]

Tracking and Enforcing Exchanges

Coordinators are responsible for managing the registry and ensuring that agreements are respected. This happens largely during a weekly monitoring session that resembles typical progress reviews in the company. Participants include members of the product management team and representatives from functional groups with pending information requests (either leaders or their delegates). The spreadsheet is shown on a large screen, and the group goes through each request, line by line, checking their status in a swift manner. The following extract illustrates these dynamics:

> *Chief Product Manager:* [reads on screen] Next! Finite elements model for flaps. [Looks at loads and aeroelasticity the supervisor who made the request] So you requested it, but it has not been delivered yet, right.
>
> *Loads and Aeroelasticity Supervisor:* Yes, let me just check my email [takes a mobile phone out and checks it]. What is the item number again?
>
> *Chief Product Manager:* Number X.
>
> *Loads and Aeroelasticity Supervisor:* [looking on mobile screen] nothing yet.

Chief Product Manager: OK, it is only due next week so let's wait for now.

[…]

Chief Product Manager: [reading] OK … next is engine deck in relation to noise.

Coordinator: Some noise specialists already presented information on it at a technical meeting [noise experts are expected to deliver the information].

Propulsion Engineering Rep (responsible for engines): Yes, but there is some concern given the changes made by the engine supplier; they might not impact noise levels, yet we cannot know it for sure until we do the flight tests [tests are scheduled more than a year from now].

Chief Product Manager: So, close that item! [Dictating to a coordinator] Write that the engine supplier declared that a change is neutral with regard to noise and that it will be confirmed later during the test campaign. Next…

As the extract shows, it all unfolds as if the chief product manager was checking items off from a list; most information requests are handled within a few minutes. Inputs which have already been delivered or that have a distant due date do not require much discussion: their status is confirmed and at most some information is noted down. Attention is directed to the delayed ones. Supervisors or their delegates are expected to account for the reasons which prevented them from respecting plans, and new agreements are then established (as mentioned in Chapter 4, missing deadlines is considered to be an 'offence' in PlaneCo). As a chief product manager once put it, "if someone is asking [for the information], it is because they need it." In these moments, coordinators are careful to ensure that delays and re-scheduling do not compromise key deliverables (as an information request might be tied into a chain of inputs and outputs).

Besides reviewing planned agreements, coordinators pay attention to potential misuses of the registry. While in principle it is only a record or a formalization of existent agreements, leaders sometimes do not resist the temptation of using it as a wish list. That is, submitting a request without discussing it with those supplying the information — or without waiting to hear their counter-proposal/confirmation. When I spoke with workers about this issue, they usually reflected on it by saying that like any other tool, its benefits are in the hands of users (which is another reason why monitoring its use is important)

The Registry as an Optional Tool

There are no fixed rules stating which information requests ought to be (or not) recorded: workers are expected to use their best judgment for this. There is not even any norm requiring employees to use the registry. While spending time among workers in the engineering unit, I observed that "off record" knowledge exchanges were relatively common. For example, when shadowing a coordinator who was responsible for the aerodynamics groups, I documented many discussions about information exchanges, as shown in the vignette below:

> X walks down the corridor to talk to a senior engineer (an ambassador) from the environmental control systems (ECS) group. First, X asks information about the ECS of a new commercial jet [a program management colleague had sent an email requesting information on this earlier to him]. The ECS expert explains some key features of the system and X inquiries further until he is confident he "understood all the details." He then asks the same engineer about another piece of information on the bleed outflow figures of the same plane [a load specialist from a group which is overseen by X is waiting for this information]. The same back and forth of questions and answers unfolds for the entire length of the conversation and the senior engineer promises that the information will be delivered soon.

Later in the day, I asked X whether these exchanges were common and whether these information requests had been recorded in the knowledge sharing registry. He commented that including every piece of information shared among groups in it would be "madness" and would make it "too rigid." However, he then also complains about the fact that ironically it would have been better to request the information on the bleed outflow via the registry, since the fact that ECS experts had been stalling the delivery for months was something that had escaped the attention of higher authorities, including the product development group.

No specific pattern behind the use of the registry seems to exist. I observed that some groups sitting a few meters away from each other recorded virtually every exchange, while others who were housed in different buildings across the company would sort it all informally. The only expectation apparently is that those who are close to each other in the organizational structure should be able to share information without having to make use of the registry (e.g., groups within the same small department). A senior coordinator made this convention explicit when commenting to his peers that he was baffled to learn that a supervisor used the registry to request information from a fellow supervisor working under the same manager — news met with laughter by fellow members of the product development team. Yet again, the general understanding is that, if anything, these inconsistencies are a small price to pay for the flexibility of a system which is overall perceived as positive.

Checking The Appropriateness of Requests

The registry makes the details of each information request visible in the spreadsheet. For this reason, they can be easily examined by a variety of actors, including coordinators (the gatekeepers of the system). During the weekly sessions in which the requests that have been logged into the database are reviewed, there are also many discussions on whether they are appropriate, and whether they meet the general standards of the product development.

Given the panorama of intricate expertise in PlaneCo, workers are routinely asking for inputs even from those groups which they may have limited familiarity with. Therefore, placing requests to the wrong person/group is not uncommon; not least because it is not always clear whose jurisdiction the requests fall under. I noted that workers would regularly debate whether they were the ones who had to deliver information which had been requested. For example, consider the following vignette about a review meeting:

> The session moves to the next item: a request from the landing gear group to maintenance experts about the aircraft jacking point. Before the discussion even starts, a representative from the maintenance group explains that he discussed the issue with his team before the meeting and they realized that defining the jacking point is beyond their competence and that it is actually the responsibility of airframe drafters (although the drafters do this according to the requirements they provide). Thus, the request should be directed towards them. He then reports that he has already informed the landing gear group about this a couple of days ago and they agreed with it.

As the extract illustrates, a request was made to the landing gear group. Yet it turned out that they were not the ones who were the most qualified to provide such information, even though it depended on inputs from them — as in an information cascade, which was common in PlaneCo.

Other adjustments are slightly more challenging, such as, for instance, when a request is made at the 'wrong time.' Being a formalized process, there are precise stages for the release of particular information in the product development — e.g., calculation results, design definitions, drawings and so on (see Chapter 4). At the same time, experts work under a regime of concurrent engineering and must provide preliminary information to each other. Thus, negotiations about which information may be demanded at a given development phase are quite common. The most salient one I witnessed happened when a chief product manager suggested that a flight test specialist edit his request:

> Your request, [flight test expert], seems a bit out of place. What you need is the medicine, not its package, so to speak. You do not need the ICD [Interface Control Document], you need the interfaces to be well-defined. According to [the product development model], the ICD is approved only at the CDR [Critical Design Review — taking places months from now]. So you cannot place a request for the ICD before … but if what you need is not necessarily the document, but some preliminary information on the interfaces, that is what you need to put on the record.

The flight test engineer had asked for documents which in principle are only produced in a development phase which was still months away. The chief product manager then explained that the request was inappropriate adding that if only some preliminary information was enough, he should edit the request accordingly.

Detecting Interdependence Problems Via the Registry

The registry also makes it possible to notice shortcomings in the product development that would otherwise remain dormant. According to many informants, knowledge flows are also a thermometer for the health of product development. Behind delays in information sharing there might be a group facing problems. Thus, being able to visualize and keep track of exchanges makes it easier to assess whether reasons for concern exist. I observed that during weekly reviews of the registry, product management coordinators asked representatives from expert groups about the causes for delays and equivalent shortcomings. At times, this revealed that progress had been compromised by personnel deficits, problems with external suppliers, or even technical issues, leading coordinators to take action. A discussion between an airframe drafter and a chief product manager serves as an illustration of this point:

> Item X. OBIGGS size [On-Board Inert Gas Generation System]. Information requested from an airframe drafter to a fuel systems engineer.

> The requester explains the need to have a definition on the OBIGGS size. Some participants at the meeting disagree with the appropriateness of the request, claiming that the OBIGGS does not interfere with the geometry of the fairing around it [designed by drafters]. For this reason, its dimension is irrelevant. The requester disagrees, insists that a definition was promised, and that its absence impedes the design of an area neighboring the component. The chief product manager speaks up, asking whether any detail on the OBIGGS is currently available in the digital mock-up. To his surprise, nothing is there, yet. He then decides that this represents a technical issue as it may compromise the design of some systems and asks his subordinates to include it in the list of topics to be discussed in an upcoming technical meeting.

The vignette above shows a situation in which there was disagreement on whether a piece of information was pertinent or not. According to the requester, without it, the drafting work would be compromised — a position disputed by others. The chief product management then intervened; he found out that no design details about the component were available on the digital mock-up, so he decided to address the issue in another forum since he believed that it could compromise product design activities.

The gains introduced by the registry are even more visible when it reveals possible risks for the product development as a whole. Because exchanges are tied into chains of inputs/outputs, the inability to deliver information within expected timeframes might impact the progress of projects. For example, a debate on a delayed exchange revealed problems with a contractor which could endanger the plans for the test campaign:

> [Information has not been delivered yet because interior systems engineers are unsure about the functioning of a piece of equipment supplied by an external company]
>
> *Coordinator 1 (overseeing the group providing the information):* analyses are being carried out … but we are not sure about how smoke detection will unfold.
>
> *Coordinator 2:* Is the sensor the problem?
>
> *Coordinator 1:* Yes. It is new … [a supplier company] is working on it, but depending on how it goes, it might lead to changes in the test beds.
>
> *Chief Product Manager:* Then, this is no longer a knowledge exchange matter, it is a risk for the product development process!
>
> *Coordinator 1:* Yeah, but solutions are under development already. We will start with [another aircraft from the same family] and then move to [this plane].
>
> *Chief Product Manager:* I understand, but it is still too large of a problem. Do me a favor [tells subordinate], add this issue to the risk database.

As the extract shows, a piece of information was delayed because interior systems engineers were facing problems with suppliers. Since this could impact work on test beds, a central moment in the product development of an aircraft, the chief product manager insisted in creating a new entry into the risk management database despite some (light) dissent from the coordinator overseeing such activities.

Written Down Knowledge Exchanges

The knowledge sharing registry is not merely a visualization instrument (as the DSM is originally intended), but a bureaucratic tool used to formalize agreements and enforce them. Details about information requests are written down in a publicly visible database and monitored routinely by the product management group. Coordinators see to it that requests are appropriate (made to the right people and at the right time) and that due dates are followed through. The formal character of the registry provides at least three noteworthy benefits for knowledge exchanges.

First, formalization provides agreements about exchanges with a mandatory connotation. Due dates are not only verbal promises: they are objectively recorded making it all the more transactional and calculable. In case a party does not follow these agreements through, they are liable for breaching what is documented in the registry. This serves as an incentive to keep experts in line — and this is particularly relevant since groups work under a strict timeframes and are enmeshed in chains of inputs/outputs. For these reasons, having a stronger degree of certainty that agreements will be respected is of great importance here.

Second, when exchanges are recorded in a public database, they become an official company matter. They are thus liable to the company's norms and procedures (e.g., product development guidelines), and they fall under the scrutiny of managers and peers in the monitoring processes carried out by product management teams. Such involvement would be less likely to occur — or would take place in a less structured manner— if the information exchanges were merely a one-to-one private matter. Indeed, as illustrated above, experts sometimes complain about the absence of scrutiny from authorities when problems emerge in exchanges (see vignette above about coordinator overseeing aerodynamics group).

Third, the registry makes such exchanges explicit and hence more easily manageable. As a centralized database, it can be consulted by anyone and shows which inputs have been requested, by whom, to whom, and with what due date, etc. This visibility helps managers to better organize work activities. Functional leaders gain a straightforward list of information required from their groups which they can then use to plan and prioritize tasks (more on this in Chapter 8); and product/program managers may scan it to check the status of product development work and target emerging problems, such as delays (see example above on possible delay on test rigs).

The Information Collector: When Information Exchanges Resemble Economic Transactions

Although the knowledge sharing registry is used within and across all specialist groups, drafters have created additional tools to regulate all kinds of information sharing which they are involved in (the reasons behind this are explained later). One of these is an "information collector" tool which I explore in this section. This tool is used to request information from engineers regarding technical drawings. First, I review its origins and explain how it is used to encourage engineers to provide the demanded information in a timely manner. Then, I explore how the tool helps in teasing out the responsibilities for delays in product development between engineers and drafters. Finally, I explicitly discuss the bureaucratic dimension of the information collector by pointing out that it makes information exchanges more impersonal and traceable.

The Tribulations of Drafters: "I Needed the Information by That Date!"

Drafters depend on information from a variety of engineering groups to get work done because this information specifies the characteristics of the aircraft components (e.g., diameter) that they draw in the digital mock-up. For example, a drafter sketching a wing rib follows the definitions provided by structural, material, and manufacturing engineers. The process, however, is cyclical. Drafters work out the physical interfaces among aircraft parts and provide feedback to engineers on whether the specifications are attainable or not. At the end of a back and forth process spanning months, drafters release technical drawings which are then signed off by the engineers and go into production.

Although the work of drafters and engineers is highly interdependent, the former occupy a lower status position (see Chapter 4). This would not be a problem if engineers respected drafters' demands. A critical milestone in the product development is given by the release of drawings for production which follows a tight schedule. Drafters thus expect engineers to deliver information about the final specs of aircraft parts on time so they may complete the design by the release deadlines. However, engineers often deliver such information late, or ask to change specs at the last minute, thus forcing drafters to push schedules back. In other words, because they receive information late, drafters are unable to finish drawings in time and end up missing product development targets. Yet, since engineers have the upper hand, this usually goes unpunished.

When explaining this situation to me, a senior drafter showed me a video he had prepared with colleagues, a sort of amateur comedy sketch about their tribulations. It showed a drafter holding a drawing he wants to release to production. He goes to see the engineers, sitting at their workstations, to get them to sign it off. However, as he approaches them, they add alterations to the drawing, hand him post-its with to-dos, while gesticulating to indicate that he should come back later. The drafter then goes to his workstation, edits the drawing, and tags it as final. Again, when he goes to see the engineers, they still ask for some modifications in a never-ending spiral. Although exaggerated for comical purposes, the senior drafter insisted that the video closely captured their routine — an impression I had the chance to confirm throughout my fieldwork. As I once overheard a drafter complaining to an engineer, "I told you we needed that information by last week … now our plans have gone out the window!"

Besides some overall annoyance, this generates considerable problems for drafters. They are the ones who 'push the buttons' to release drawings to the manufacturing. For this reason, responsibility falls on them for delays, even though the cause may be the lack of information from engineers. As I mentioned previously, being accountable for delays means being in a tight spot in PlaneCo (see Chapter 4). However, without having any objective way to show the (real) reason behind the problems in the work progress, drafters are locked into a powerless position. Reflecting on this, an ex-drafting supervisor remembered a progress review in the following way:

> We were in this meeting room, supervisors, managers, all that. The chief product manager was furious … the director of the engineering unit was there too … he would have skinned us alive. He looked at me and said: "Why are all these drawings delayed? We cannot possibly go on like this!" He had a spreadsheet and graphs showing how much off-schedule we were. I did not have any way to contest. If I were to say something, I would have had to stand up, looking at every engineering leader in the room, and say something like 'this guy here owes me information on the coating, the other owes me the diameter, that one still did not define the supplier, and so on.' But all I could do was endure the scolding.

The situation narrated by the drafter was visibly distressing yet not uncommon in PlaneCo (some leaders are known for raising their voice when projects get off-schedule, especially when close to milestones). As the drafter explained, the project faced delays because engineering groups owed information to drafters. Still, drafters were blamed as there was no instrument to hold engineers accountable — information was exchanged in an informal manner and there were no objective agreements which they could refer to.

An Invoice for Drafters Requesting Information from Engineers

The situation changed when some drafters proposed to formalize the information exchange process with engineers (this happened some years before my fieldwork). The idea emerged in continuous improvement sessions and resulted in the creation of the information collector. The tool was first implemented in the development of a small jet. Drafters advocating for it obtained permission to pilot it in a group designing an aircraft segment. Results were outstanding: the technical drawings of that group were delivered to manufacturing much earlier than the ones from other groups. After this trial, the use of the information collector was extended to all PlaneCo projects.

From a technical point of view, the information collector is a plug-in in the product design software. It solicits, stores, and confirms the receipt of information from various engineering groups for the drawing of an aircraft part. As for the rest of the design cycle between drafters and engineers, most of it still unfolds informally. Yet, once the design features have been finalized (in light of the specs from the engineers), a drafter sends off an information request through the information collector. Engineers are then notified via email and must upload the results of analyses and their comments in the database with a certain timeframe (generally within a month). The system automatically generates metrics on whether information has been delivered or not within the deadlines. For structural parts, the system is pre-set to request information from structural, materials, and manufacturing engineers, as established by design norms. In the case of the technical drawings of other components (e.g., electric cables, oxygen tanks), drafters 'manually' select which engineering specialists they want to request the information from.

An informant used an interesting metaphor to describe the collector: an invoice system (this is why I use the word 'collector' as a pseudonym). Expanding on this idea, we can say that through this tool drafters 'bill' engineers for the information that they 'owe' them. Engineers must then 'pay' them by uploading the information to the database within a specified deadline. If this happens within the appropriate time, the 'bill' is paid off. If not, it goes on a list of debtors.

Similar to the knowledge sharing registry, the use of the information collector is optional (albeit the tool is strongly popular and widespread throughout the company). Drafters have the freedom to employ it or not in the drawing of a part number (each part number has a technical drawing associated with it). According to one of its creators, this prevents the tool from becoming too stiff or 'bureaucratic'. In his words:

> It is up to each individual to decide if they want to request the information for the part number via the tool or not … to avoid 'bureaucratizing' it too much. After all, this is a process that bureaucratizes or formalizes exchanges a bit. When I request the information through it, engineers have to upload a file there, even if it is an empty one ... otherwise, the system does not move forward.

Unlike the knowledge sharing registry, the collector is not associated with a monitoring routine. However, the metrics from it are used in periodic progress reviews of the release of drawings led by product management teams. Since the information collector indicates whether a drawing completion depends on drafters or engineers, it serves to help coordinators direct their forces to ensure work progress (I discuss this routine later).

Getting Engineers Into The Product Development Rhythm

As suggested before, drafters and engineers are continually exchanging information and editing technical drawings. Thus, it is necessary to qualify in greater detail the previous points: the drafter's tribulations are not so much about getting information for the drawings, but receiving the 'final' specs on time. Drafters complain that engineers occasionally alter specifications after they have already agreed on the design of a part (causing drafters to have to re-work the part drawings and potentially upsetting deadlines). A drafter described this dreaded situation in the following way:

> So, imagine, I am ready to release the drawing of a spar to production. I go up to the engineer and say, "Here is the final design, with the dimensions you provided me with information on" … In principle, all is good to go. Yet the release day arrives and the engineer comes to me saying: "Hey man, after some flutter analysis and what not, I think we need to change the part's geometry in this or that way." So I have to re-design it. The problem is that it is already the due date for release, so everything gets delayed. … I mean, back then everyone [the engineers] said "OK" when I showed the drawing. But close to the finish line, they want to change the structural design and we [drafters] are the ones blamed for missing the deadlines!

This interviewee reports an issue which everyone can probably empathize with (academics in particular). Common sense says that the work ends when time or resources run out. However, since the engineers were not directly accountable for the release of the drawings, they continued to revise their calculations unfettered (leaving drafters in hot water). As some drafters put it colorfully, engineers would promise that certain information was 'final' only to change their minds at the last minute.

Another drafter reflected on the same matter while sharing a story. Years ago, he was working on the design of an executive jet. Around the time in which the first test planes were being produced, a junior structural engineer came to him saying he had discovered an improvement opportunity for an airframe part and wanted to alter some of its structural characteristics. What the engineer had not realized was that the first test plane had already been produced (thus changes could only be made via the formal change process). In an amusing turn of events, the drafter took the engineer to the other side of the office floor and asked him to glance through the window. He then said, “You want me to change the design of a part in that plane? *The one standing on the runway there*?” The poor engineer was astonished. The drafter then told me this case illustrated well how much engineers “do not feel the ‘heat’ of product development” in the same way as they do.

The information collector changes this mismatch into ‘work rhythms’ by putting engineers to work to the same ‘beat’ as drafters do. It pushes them to deliver the final specifications within a particular deadline following the requests from drafting groups. If engineers fail to comply, the system shows them as responsible for delays; if they deliver the information but change their minds later, the system still indicates that they did not live up to their promises (and are therefore responsible for the delays). With a formal system in place, what counts are not the intentions (‘I promise this is the last version!’) but what is written down.

Putting Accountability Where It is Due in Interdependent Work

While the knowledge sharing registry is used throughout product development, the information collector only appears once drawings are closer to completion. This is one of the most crucial moments in the development process since the production of the first test planes (and thus the test campaign) hinges on the release of these technical drawings. Hence, there is much anxiety around work progress and drafters are pushed to meet deadlines (overtime is common during this phase in PlaneCo). Although in the past only a general list of delayed drawings was available, now the list also shows which engineering groups have not delivered the specifications.

The importance of the information collector in elucidating accountability is particularly visible during progress reviews. This is especially true for those set to monitor the release of drawings for production. In light of the company’s attention towards close monitoring (see Chapter 4), periodic sessions take place to check on the release of drawings. This happens through a daily meeting organized by a senior drafter and it includes the chief product manager together with his/her subordinates (i.e., coordinators). It lasts around 30-40 minutes (which is brief by PlaneCo standards). A large screen displays a spreadsheet which is reminiscent of the one used in the knowledge sharing registry (and general progress reviews). Rows feature the aircraft parts while the columns list, among others, the part number, its owner (usually a coordinator), the planned release date, the progress status (e.g., expected, delayed), and the status of the information collector.

The meeting unfolds as most progress reviews do in PlaneCo. Reflecting on the importance of individualized responsibilities (see Chapter 4), each aircraft part is linked to a coordinator, who is accountable for its status. The review unfolds with the senior drafter and a chief product manager checking each line of the spreadsheet. When there are delays and similar problems, the chief product manager demands explanations from the coordinators. The snapshot below conveys a bit of the meeting ethos:

> It is 8 AM. The drawing release review is taking place in a small room. A senior drafter, who invited me to the event, sits at the end of an oval table at a computer. Behind him stands the chief product manager. Coordinators are sitting or standing around, holding notebooks, time charts, and other documents. On the screen, a spreadsheet lists the delayed drawings (some of which are two months late).
> […]
> The senior drafter calls out the delayed items prompting an explanation from the coordinators. Some common justifications are "it will be solved today," or "I just got confirmation from [name manager] yesterday it will be released maximum tomorrow." As they go through each part drawing, the drafter colors the spreadsheet rows — green (done), yellow (release expected today), red (delayed) — and adds comments for the technical drawings that are in more critical situations. At times the chief product manager looks at his notes, asks about the status of a particular part, and recommends prioritizing some items over others ('we need to focus on primary structural parts at this stage').

As the extract suggests, the meeting is a typical monitoring session: delayed drawings are announced, plans are presented, and so on. It has a rapid pace, some coordinators only come in for a few minutes to check the status of the drawings they are responsible for, to explain delays, and to re-plan deadlines. Occasionally, the chief product manager turns the heat up and orders groups to work over time to compensate for the delays.

The information collector is used to untangle the reasons behind a delay. As explained previously, drawings might be delayed because drafters have not finished them yet, or because there is missing information from engineers. It is in this latter situation that the information collector is useful, highlighting the fact that engineers are the ones blocking the process. Besides making the process fairer (drafters are no longer unjustly blamed), the information collector makes the monitoring process a more precise activity. It gives coordinators/managers a more accurate view of the status of the drawings release, so that they can direct their efforts appropriately (i.e., pressuring specific groups for delayed drawings). When I sat in the meeting, I noticed that afterwards coordinators usually ran off to investigate the causes behind the delays, sometimes coming back to the same session with new information on work progress (or with other problems).

'Automatizing' Information Exchanges

The information collector reflects drafters' efforts to make engineers deliver information timely and live up to their promises (e.g., on what specifications are truly final). It also elucidates the responsibilities (for delays), giving functional managers and coordinators a bit of an edge when dealing with interdependent activities. Like the registry, it indexes exchanges in an official manner. Yet, the records are not publicly visible and the agreements are not (only) 'manually' monitored. The process is slightly more mechanical and embedded within working tools: information requests are sent directly to the engineers via the design system which automatically registers when information is uploaded. When the system generates metrics on which drawings are delayed, it points out whether this is caused by missing information. The 'automatic' nature of the collector highlights its bureaucratic dimension and influences knowledge exchanges in two important ways.

First, it makes knowledge exchanges more impersonal and democratic. Requests become more factual as in a formal (economic) transaction. They take place through an automated email, a mechanical intermediary between experts. Personal status is removed from the exchange, and so are informal promises: the relevant bonds are the ones registered in the collector. This relates to the democratizing effect of bureaucracy (further explored in Chapter 8), which is particularly pertinent in the — tribulated — interactions among drafters and engineers. By bureaucratizing exchanges, the collector minimizes status differences and promotes fairer relations. Engineers must upload information in a (cold) database which they cannot argue with or have their own way with (as they might do when they change specifications at the last minute).

Second, the collector makes information requests/deliveries more traceable. Without it, the details about information exchanges would be scattered around in private notebooks and in people's heads. Now, anyone with access rights to the system (e.g., managers) can check when the information was requested, from who, to who, when it was uploaded, etc. It also shows the status of the release of drawings vis-à-vis information delivery for thousands of technical drawings. Such traceability contributes to tuning engineers to the same rhythm of the drafters (as they know that they are liable for delays) and gives leaders a surgical precision when handling delays and related problems.

Communication Standards: When Experts Use Codes to Embed Messages into Drawings

The third knowledge exchange tool is another one that emerged in the drafting universe and is used by drafters to share design information among themselves. These are communication standards which make it possible to embed information about a design part directly in the digital mock-up system. In this section, I explore the standards and how they facilitate communication among drafters while playing an important role in the resolution of occasional disputes. I then consider how this is possible thanks to the codification introduced by communication standards which make information exchanges more straightforward and provide objective traces of agreements.

Seamless Communicating in Parallel Activities

Drafters are constantly interacting to get their work done with peers as much as with engineers. Hundreds of individuals work in parallel designing thousands of components in the digital mock-up. Given the tightly-coupled nature of aircraft systems, drafters must continually adjust their drawings in light of the interfaces with those created by others. They largely specialize in airframe, mechanical, and electrical design making up distinct groups and working according to particular requirements. For example, airframe drafters worry about creating parts with a solid geometry in light of fatigue requirements; mechanical and electrical drafters, instead, stress over the task of fitting cables and wires within tight spaces while attending to stringent installation requirements (the cables of a commercial aircraft can reach hundreds of kilometers if stretched). Although interactions among drafting groups are overall smooth, misunderstandings still do take place.

Strains are particularly prominent when mechanical or electrical drafters request airframe peers to adjust designs in order to make space or create mountings for components (e.g., a hole in a wing rib for cables to pass through). Since such 'holes' and 'supports' are part of the airframe, they fall under the jurisdiction of airframe drafters. Thus, mechanical and electrical designers are in the uncomfortable position of having to continually ask them for adjustments required by the systems they design. During my fieldwork, I noticed that airframe specialists were often mildly annoyed by these requests.

To order interactions — and liberate mechanical/electrical designers from a 'dependent' position — drafters proposed to formalize communications by borrowing the logic behind existent interface protocols. Employees from various companies work on the design of aircraft parts and, as virtually all aircraft organizations, PlaneCo uses a formal system to order design interfaces with suppliers, the so-called Interface Control Documents (ICD). Inspired by them, drafters proposed to create internal standards for design work. A senior designer explained the thinking behind this in the following way:

> Interfaces between [a supplier] and PlaneCo are regulated by an ICD. This spells out where the work of one ends and the other starts. The [communication standards] are no different … and were created because in the same way that it is important to prevent problems of interfaces between PlaneCo workers designing a wing and suppliers creating a wing box, there can also be issues internally among drafting groups.

This senior worker was involved in the creation of the standards which were implemented a few years before my fieldwork. As he puts it during an interview, interface problems may happen within the company as much as with suppliers, which means that regulations may have a role to play in both situations.

Communication standards are nothing more than a series of codes which convey information in the digital mock-up. These allow mechanical and electrical drafters to use a 'ghost' part (one that does not exist yet), to show to airframe drafters the characteristics of the fixers, brackets, holes, and similar apparatuses that they require to fit the systems they design. These 'ghost' parts are also recognizable by a distinct part number and unique design characteristics, the most important being a color code. Green stands for "proposed," yellow for "in analysis/discussion," blue for "accepted," and red for "rejected".

Mechanical and electrical drafters design (in green) the elements they need directly in the digital mock-up; these are negotiated with airframe drafters who might accept them (blue), or make counter-proposals (yellow/red). Thanks to these standards, all drafters can communicate more seamlessly; and mechanical and electrical designers become more autonomous and able to directly inform (and show) airframe drafters what they need to fit the systems designed by them in the airframe. Similar to the two previous tools, the use of these communication standards is not compulsory but much welcomed and popular among drafters.

Preventing and Arbitrating Conflicts

Besides allowing for clear-cut communications (those in which some feel less 'disturbed' by others), drawings created according to communication standards also serve as records of agreement. Requests and responses regarding designs are 'registered' in the digital mock-up and are visible to all workers. All one has to do is to look in the system and here they see whether a wire bracket has been 'proposed' (green) or whether an agreement has been reached (blue). When shadowing a drafter, I observed him finalizing the design of some parts. Aware of my interest in understanding the communication standards, he confirmed that he was aware of a promise to create a hole in the rib (a wing structure). But just in case he forgot, the placeholder drawing was there: no need to consult any notes. And if for some reason he could not follow through with the agreement, the drawing would have been a reminder for him to call his fellow drafter.

Having such an aide-memoire reduces the risk of drafters carrying on with work without consulting each other. It thus helps nurturing more harmonious relations and prevents arguments from developing. An airframe drafter reasoned about this as follows in an interview:

> It goes like this … if [airframe] drafters need to modify a fixing which has already approved for some reason, they are more likely to inform the [mechanical and electrical] folks since there is an agreement which is visible in the system. The opposite is also true. This reinforces the fact that one needs to call the other, discuss, agree again, and get basically in sync about it.

As the worker puts it, the placeholder part reinforces a commitment among drafters and serves as a reminder of the need to check in with each other — what in PlaneCo vocabulary is known as 'getting in sync' and similar variants (see Chapter 4).

When breakdowns do happen, communication standards still have an important role to play. Given the objective nature of a placeholder part, it is possible to refer to it as a piece of hard evidence of an agreement. This is particularly useful in situations of conflict. A junior airframe drafter reflected on its value in these cases in the following way:

> For example, let's say there is a placeholder part for that rib, but I did not see it and made a hole in another place, so the placeholder is there and it settles the matter. It was my mistake. Likewise, it might be the case that I did see the placeholder, I did the hole as requested or anything that the system drafter might need and then all of sudden the tube or cable changed place for some reason. So I look and say, wait a minute, I did all of this because you created the placeholder there […] You [mechanical or electrical drafter] are the one who did not follow through with our agreement.

According to the junior drafter, a placeholder part created according to the standards sits there as a sort of material evidence. When there are problems, it shows whether there was an agreement and what had been promised by each party. This way drafters avoid a 'he-said-she-said' situation.

A Codified Transfer of Information

Communication standards are primarily given by a conventionalized pattern of colors and related codes which enable drafters to communicate, 'discuss' counterproposals, and establish agreements in the digital mock-up. They echo much of what has already been debated in relation to the knowledge registry and the information collector. Similar to them, these standards allow experts to place requests to peers, 'record' promises, and hold the right individuals accountable in case of breaches of promises. They also make relations more impersonal and agreements more binding; on top of that, communication standards illustrate two other consequences of employing formal channels to share information.

First, standards make knowledge exchanges more straightforward. They allow information to be transmitted instantly according to a fixed protocol recognizable to a broad audience — any drafters can see whether the creation of a wire bracket attached to the airframe has been accepted by looking at its color (Schelling 1978). In addition, instead of having to open a separate communication channel, the standards make exchanges happen in the design system used by all drafters. There is also no need for mechanical and electrical drafters to describe what they require verbally: they can show it directly in the system. All this is central in allowing drafting specialists to circulate information back and forth in a seamless manner as described above.

Second, the 'ghost' parts created according to standards not only serve to communicate design information but also to record arrangements among drafters. Anyone who knows the code can see whether there is an agreement (the aircraft part is in blue), an on-going discussion (part in yellow), and so on. As suggested by the junior drafter quoted above, there is no need to look anywhere else but the design system. This characteristic is the basis of the value of the standards as aide-mémoire; it is also what makes them take the role of 'hard evidence' in case of disputes as they show whether there is an agreement and exactly what it entails (e.g., where is a hole in the airframe expected to be).

Conclusion

Accessing knowledge from peers is a fundamental aspect of cross-expertise collaboration (Hansen 2002, 2009). When experts depend on the inputs of colleagues to accomplish their work, getting the appropriate information in a timely manner is what determines the difference between producing deliverables effectively within deadlines or not doing so. The extant literature praises the importance of deep/meaningful ties and positive work environments in knowledge sharing, while usually frowning upon formalization (Hansen 2002, 1999, Kotlarsky and Oshri 2005, Swart and Kinnie 2003, Wang, S. and Noe 2010).

Without denying the importance of interpersonal and contextual elements, my fieldwork revealed that bureaucratization may bring benefits to knowledge exchanges, particularly in a context with requisite integration, complex interdependencies, and tight deadlines such as PlaneCo. By exploring three information exchange tools (see summary in Table 6), I showed how bureaucratization makes knowledge flows more straightforward and manageable. In the next chapter, I continue exploring the relations of bureaucracy collaborative work across expertise domains by focusing on the case of experts occupying official intermediary positions.

Table 6. Characteristics of Knowledge Exchanges Tools

	Knowledge Sharing Registry	***Information Collector***	***Communication Standards***
Main Purpose	Makes it possible to record agreements around knowledge exchanges	Allows for drafters to request information from engineers in an automatic manner	Permits drafters to embed information into drawings and to communicate via them
Experts	All expert groups in the engineering unit	Drafters and engineers	Drafters
Bureaucracy	Written down agreements on exchanges with a mandatory value monitored/enforced by product management teams as per company norms	Formal information requests submitted impersonally through the design system associated with a timeframe and easily traceable	Inscribed information into drawings stored in the design archives according to fixed standards which are widely known

CHAPTER 7

INTERMEDIARIES

HOW BUREAUCRACY ESTABLISHES OFFICES FOR LIASONS AND INTEGRATORS IN THE LATERAL HIERARCHY

Carl Hammoud – Maze

Introduction: Intermediaries by Design

> *"I was responsible for flight mechanics and performance in [a certain plane]. Then the company decided to make a smaller version of [a previous aircraft], and I was invited to be the 'technical leader' in it. I think that at that time, [PlaneCo] had just implemented a matrix structure in which you have functional areas which are responsible for the workforce, and people taking care of aircraft projects. That was my job. I was in charge of making the project happen, but I did not have any formal leadership, I did not even feature in an organization chart or anything like that. […] There was no such thing as a rank from which you could boss people around to do this or that. We, as a group, had to decide what was the best course of action. So, I think it was an exercise in leadership, on cooperation, on how to capitalize on what folks are able best able to do. … I had to work things out directly with people, listen to them, review proposals. My role was to put these individuals, who had brilliant ideas, together in order to push the product development forward."*

The quotation above is from an engineering unit director interviewed by the company's historical center. Among other topics, he reflects about his experience as a 'technical leader' (the equivalent of a chief product manager nowadays) in the development of an aircraft decades ago when a matrix structure had been first implemented. PlaneCo was smaller back then, developing one new plane at a time, which meant that most members of the engineering unit were involved in the same undertaking. The situation today is considerably more intricate. Functional areas still manage the workforce, but they need to attend to a number of parallel development projects. And while the matrix structure remains, lateral relations are no longer under the responsibility of a single 'hero' working off the charts. Intermediaries exist very much by design: they occupy positions in the lateral hierarchy and are formally responsible for linking expert groups and directing them towards shared goals.

The literature on cross-expertise collaboration extensively documents the challenge of aligning and connecting workers across specialist groups and the role of boundary spanners, liaisons, and integrators in these processes (Leonardi 2011, Bechky 2003, 2006b, 2006a, Kellogg et al. 2006, DiBenigno and Kellogg 2014). However, it glosses over the ways in which formal arrangements are put in place by an organization to facilitate them. Studies about individuals linking groups within and across organizations often treat them as free agents and ignore their relation with formal hierarchy (Mohrman 1993, Tortoriello et al. 2012, Tushman 1977).

Conversely, this chapter shows that in PlaneCo there are bureaucratic "offices" for intermediaries. While the notion of "office" is usually associated with vertical hierarchy (Weber 1978), the same principle applies for lateral positions. I explore two types of intermediaries which I label ambassadors and coordinators (pseudonyms). Ambassadors are usually mid-career/senior experts appointed as representatives of functional groups for a project. While they direct some activities locally, most of their work is outward facing. The bureaucratic character of the position is clear to the extent to which it represents an "office" with associated resources and responsibilities which endures beyond particular individuals.

Coordinators, instead, are usually members of product management teams (they exist in other groups but this goes beyond the scope of the present thesis). Their activities also involve interacting laterally across functional groups, yet at a 'higher' level. They organize interdependent undertakings and cross-domain processes (e.g., technical meetings). Here again, this position has a bureaucracy dimension, as it exists as an 'office' overlaid on functional departments, and arrangement that helps them to accomplish their mandate. Overall, the chapter shows how offices disposed in a lateral hierarchy enables the work of intermediaries. In the next sections, I explore each of these intermediaries separately and offer some concluding remarks at the end.

The Ambassador Office: Liaisons Among Expert Groups

In PlaneCo, most workers interact extensively with fellow specialists as part of their daily activities in the product development. In these (lateral) relations, there is a clear definition on who represents an expert group in official forums and mediates the exchanges among groups. These points of contact are represented by the individuals assigned as ambassadors. Although they echo what the literature describes as liaison roles or boundary-spanners (Allen, T. J. 1977, Lawrence and Lorsch 1967b, Mohrman 1993), here I use the term 'ambassador' to stress their official status as part of the organization hierarchy. I start by presenting the profile and routines of these individuals and by exploring their work to enable collaboration across expertise domains. I then unveil the bureaucratic underpinnings of the ambassador position and discuss how it provides these professionals with resources to carry out their activities.

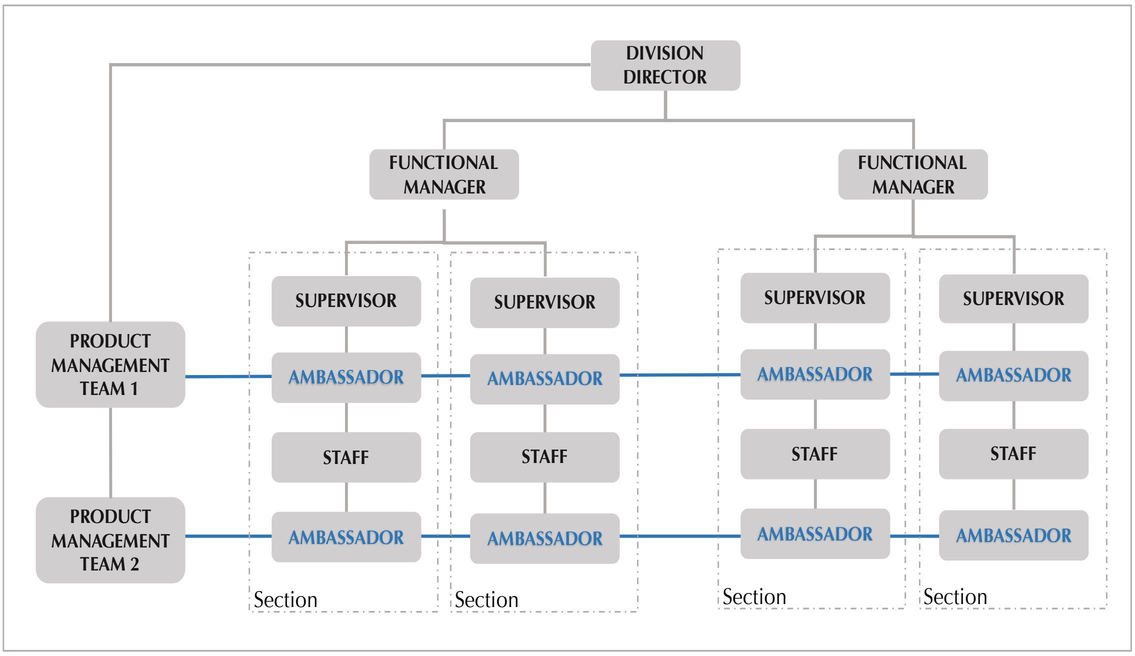
Who Are the Ambassadors and What Do They Do?

Ambassadors are the first step in the lateral hierarchy of PlaneCo. They are entry/exit points for information; spokespersons in cross-expertise meetings; go-betweens in negotiations; and the representatives of expert groups in the engineering unit. They are selected by functional leaders usually among mid-career/senior workers and they become to an extent their mirror image on the horizontal axis of the matrix (sometimes supervisors occupy both positions). Their appointment, however, does not involve many formalities (new functional leaders, instead, go through a planned training course), nor are there specific work procedures that must be followed (they structure their activities according to their best judgment).

While supervisors connect workers up and down, ambassadors do this laterally. Supervisors handle communications and commitments vertically and may oversee workers who are allocated to multiple projects. On the other hand, ambassadors concentrate on lateral matters related to a single project (there is usually one ambassador per product development project). Figure 17 presents a schematic representation of this arrangement. Obviously, functional leaders interact 'laterally' and participate in project meetings — not least because they hold the last word on various themes, including resource allocation. However, they rely on ambassadors to act as their delegates in regular cross-domain activities and to help manage work tasks within functional areas. Ambassadors also offer support for the most technical aspects of the work, leaving supervisors free to handle human resources issues (e.g., hiring, holidays, training) and administrative responsibilities (e.g., annual planning).

Becoming an ambassador does not automatically bring material gains, but it may help with career progression. Mainly because it requires them to dialogue with representatives from areas beyond their specialist field, an ability which is deemed to be part of the professional development of engineers and technicians. The position also brings some share of prestige, as it puts a person in contact with many groups, thus providing him or her with a certain level of visibility. This, however, comes with a price, as the job proves to be daunting at times. Ambassadors receive requests (and complaints) from all directions and must advocate for their group in many forums (e.g., technical meetings). In the next section, I explore these activities in detail.

Figure 17. Ambassadors' Position in The Organization Structure



A Day in The Life of an Ambassador

Taylor is an ambassador in the ECS drafting group, which has circa a dozen employees. He arrives early in the company, around 7:00, to handle emails and gain some perspective on the status of activities before the meetings and interactions begin.

At 8:20 he goes downstairs to speak with structural engineers about the interface problems of a component (pre-cooler) which his team is responsible for the design. Manufacturing engineers signaled that the current designs do not respect the minimum distance required for the assembly process. Taylor and the structural engineers check the digital mock-up and confirm that the current distance is larger than what the manufacturing engineers had thought, and should be thus enough for production.

With this new information, and the agreement of the structural engineers, Taylor visits the manufacturing engineering group. It is around 9:00 when he greets a manufacturing engineer, an old acquaintance of his. At first, she is happily surprised that the issue seems resolved, yet the manufacturing simulation software still signals a problem. She agrees to further check the situation and asks Taylor who is the person in the drafting team she can reach out to discuss it (later in the day she pays a visit to the ECS drafting area to speak with this person).

During the rest of the morning, Taylor goes to a planned meeting with the supervisor and the ambassador from the ECS engineering team; he schedules more meetings; and together with a senior drafter, Taylor reviews information requests made to the ECS drafting team. He is glad that a meeting scheduled with a top-tier supplier is canceled so he can use the time to reply to the emails accumulating in his inbox.

> Just after lunch, around 14:00, a small group of coordinators and noise engineers show up at Taylor's workstation. The goal of this unplanned meeting is to assemble information on a possible requirement modification and work out the concerns of all parties before taking the issue up to the chief product manager (possibly in a technical meeting). After the meeting, Taylor writes up the next steps which have been agreed (action points) for each person in an email.
>
> The rest of the afternoon progresses smoothly. The main disruption is a visit of Taylor's supervisor around 15:45, during which Taylor updates him about the status of conversations on the pre-cooler issue and the general work progress in the area. After that, he replies to more emails, edits a schedule, and reviews some work recently completed by his peers. He leaves the company at 17:00.

Ambassadors are important devices for the collaboration dynamics of PlaneCo. As the vignette above shows, their routine includes a succession of interactions and exchanges. For example, Taylor is usually on the beat, going around the organization, talking to individuals, circulating information. In a single morning, he visited four different groups across PlaneCo to problem-solve, 'defend' the position of his team, and communicate the status of information requests made to his group. Not all ambassadors have such a hectic routine: their activities vary according to the level of seniority, the size of the group they represent, their relation with supervisors, and not least personal style. Still, three activities are prevalent across ambassadors in PlaneCo.

First, ambassadors connect experts. When someone needs to contact a member of another group, they can resort to the ambassador. This is of particular importance because it is not always clear who is responsible for specific issues in a given area (and how receptive they might be). For example, in the case of Taylor above, after the meeting with a manufacturing engineer did not resolve an ongoing problem, he told her who was the drafter responsible for a given component.

Second, ambassadors buffer and filter interactions and requests involving their groups. To that end, they represent peers in the many forums bringing together multiple experts (e.g., technical meeting) and they oversee knowledge exchanges among specialists (e.g., requests made via the knowledge sharing registry). Thus, they buffer peers, so they are not overburdened by matters that do not require their attention at once. Also, before they pass updates along, they filter and direct them to the appropriate individuals. This is also visible in the vignette above. Taylor interacted with specialists from multiple areas on behalf of his group, while keeping his drafting peers abreast of the outcomes of the negotiations and of the problem-solving discussions.

Third, ambassadors adjust tasks within their groups according to interdependencies. Given the more comprehensive perspective of ambassadors (looking outward from groups as much inwards), they are well-suited to prioritize tasks according to interdependencies. In this process, they also defend peers from the requests they deem to be inappropriate. This is quite visible in the previous vignette. Taylor created schedules, planned tasks, and reviewed progress. In all this, he paid particular attention to the commitments with other groups. In the next section, I explore each of these activities in greater detail.

Connecting Experts Across Groups

"If I need to talk to someone about aerodynamics, I just go to the [ambassador] over there," says a mid-career engineer during an informal conversation. The problem of 'who to talk to about what' is common to knowledge work and especially salient in complex environments (Johnson, 2006). Many functional groups in PlaneCo oversee specific aircraft elements (e.g., engines) and product development processes (e.g., safety analysis). Hence, one can easily get lost in this place. As another engineer revealed while talking about the main barriers to collaboration in the company, "for me the main difficulty is reaching the right people, there is so much human capital here and specialists of all sorts … so if you can get to the person you need, work progresses well."

PlaneCo does have an internal database listing the contact details, specialization and functional affiliation of employees — a form of internal yellow pages. Nevertheless, the problem is not only where to find someone but also understanding which specialist to contact regarding a given issue in the first place. There is a whole range of sub-specializations within groups. An employee that needs to discuss loads, for example, will soon find out that within the loads and aeroelasticity group specific workers concentrate on the load analysis of different aircraft parts (e.g., pylon, wing, empennage, etc.). Even when the relevant sub-field/expert is clear, there may be interpersonal issues in the way: some people are simply more responsive (and sociable) than others. An ambassador reflected about this in the following manner during an interview:

> *Ambassador:* I think that a challenge for collaboration here is finding a person who is available to help you … it seems trivial, but it is not.
>
> *Interviewer:* Why is it so?
>
> *Ambassador:* Because of the non-availability of people. Say I need to discuss something with the supply chain department ... like I need them to close a time delicate deal with a supplier of optional equipment. But it is exactly when I need them, that I cannot find someone who can help me with it.

As the ambassador interestingly puts it, the issue of reaching out to people is not only one of 'wayfinding,' but it is also a matter of enlisting commitment to the many (and time sensitive) tasks of the product development. It is in these moments, when workers struggle to secure the participation of experts, that the support from ambassadors becomes particularly relevant (this is discussed in greater detail below). These are situations that ambassadors considered quite delicate. As one of them put it, "when workers come to me, it is because they have already tried once, twice … but did not manage to get what they needed from someone … for this reason the task ahead of me is not an easy one."

I discovered how much individuals rely on ambassadors to reach out to others (who are unfamiliar to them) and to ensure their cooperation quite spontaneously, given the efforts I made to contact different groups in PlaneCo. When I asked informants to suggest someone I could talk to in a given area, they frequently put me in touch with people they deemed suitable to show me around and enlist new contacts. Interestingly, many of these were ambassadors. As fieldwork progressed, I could confirm that these professionals were the go-to people for employees as well, including functional/project leaders. For example, they figured prominently in the contact list of all the chief product managers who I interacted with; one even had a phone directory taped to his desk next to the telephone of all the ambassadors (and managers) involved in the aircraft project he was overseeing.

Ambassadors are well-aware of their connector role and they consider 'being known' as something crucial to ensure that communication channels are operative. This comes naturally for those who have been 'in office' for a long time or whose group has activities that entail many interdependencies. Indeed, after attending cross-domain meetings for a while, I noticed that individuals referred to company areas by their title as much as by the name of their ambassadors: people would speak of "X's group" as much as of "the ECS drafting group." On the other hand, junior ambassadors and those from areas with a more limited jurisdiction actively cultivated ties and participation in many forums so that workers would become familiar with them and would therefore be able to reach out to them in the case of need. An ambassador from the flight tests department who had taken the position only a few months before shared the following reflection after I invited him to consider the main requirements for doing his job in an interview:

> I think that at the beginning it is important to take part in as many situations related to the project as possible. Even if you have to spread your participation thin, you should go to as many gatherings as possible, so you get to know everyone, and they get to know you. This way you understand who are the people involved in the project and they become familiar with you, so they know who to look for when they need something [regarding flight tests].

According to this ambassador, getting involved in gatherings related to a project is paramount. Only once ambassadors are 'in the know,' they can start selecting which events are most relevant. The reasoning is that if people are unaware of who to reach out to, the relations between groups is compromised.

Buffering and Filtering Interactions and Requests

Participating in cross-domain discussions and taking the time to understand the concerns of distinct experts is part of the work routine in the engineering unit. However, this directs the focus of specialists away from their core (functional) tasks. For this reason, groups must remain attentive to the resources which are invested in them. Ambassadors help in this by acting as buffers. They represent groups in cross-domain events and interact with expert areas to gather news and sort out emerging (interdependent) issues. Indeed, they are the ones attending technical meetings and the reviews of the knowledge sharing registry (see previous chapters). As an engineer commented, "It might all seem like an endless number of people in these [technical] meetings for you, but soon you will realize that folks are always the same [mostly ambassadors]." Taking further their work as representatives, some ambassadors sit part of the week close to those expert groups who have the highest number of interfaces with their group (very much like a diplomatic representative in a foreign country).

Limiting interactions to a few individuals also facilitates relations. It releases workers from having to agonize over who exactly should be contacted, who to request information from, or to invite to meetings. As discussed before, there are many sub-specializations within groups. So, reaching out (or finding) the 'right' person can sometimes be challenging. Ambassadors are the solution to this matter: they are known by virtually everyone and represent a group for all practical purposes. For example, a chief product manager explained once in a casual chat that he did not communicate with all the (hundreds of) workers involved the project he oversaw, but only with the "ambassadors and functional leaders … who I rely upon to further diffuse my orientations."

The buffering work of ambassadors also makes collaboration across expertise domains more economical: most experts within a group can continue to concentrate on their (specialist) activities and only partake in lateral relations when a particular demand exists. During an interview, an ambassador from a drafting group said the following:

> You see, there are so many meetings … conference calls with suppliers, [technical] meetings, project reviews … so I try to attend them to free the folks here. You know, to give them time to carry on their tasks. Otherwise, they will be going from one event to the other, the whole week, and no one can get on with work in this way!

For this ambassador, it was important to go to as many gatherings as possible to avoid disturbing the (functional) work within his group. Later in the interview, he qualified his statement, explaining that in situations with sensitive or highly-specialized issues, he is glad to take the backseat; yet he might still "take the person there", while keeping an eye on how interactions unfold. Apparently, even when ambassadors do not carry the burden of interacting with different experts, they still monitor relations to make sure they unfold smoothly. Indeed, I observed ambassadors routinely asking workers to CC them in email exchanges with specialist groups regarding technical issues or information requests.

Ambassadors also have an active role in filtering relations among groups. As we know, there is a whole range of information circulating among groups (see Chapter

6). Ambassadors help to create a 'door' for these inputs and outputs, reducing the overload on specialists. To have someone keeping track of requests makes them more manageable. Especially because communication is far from perfect and occasionally workers are not aware of demands to their groups (e.g., some information requests are logged into the knowledge sharing registry unbeknownst to those supplying it). As an ambassador explained, "sometimes there is a demand for us that we are oblivious to … so one of my responsibilities is to keep track of what inputs are requested from us."

Similarly, this filtering work is also visible when information arrives to groups. Because ambassadors are usually the ones in cross-domain meetings, they (only) forward to fellows the information which is relevant for them. In a way, this reduces the complexity of the 'external' environment. For example, just after a technical meeting, an ambassador from the program management showed me the notes he had taken and explained that he saw his role as that of primarily screening for the information that is relevant to his peers (and forwarding it to them).

Adjusting Tasks According to Interdependencies

Given the interconnected nature of product development in PlaneCo, experts depend on inputs from various colleagues to define the characteristics of the aircraft systems which they work on (the outputs of some are the inputs of others). Hence, activities within groups must take into account the demands of others. These relations — like any other — are not always straightforward and ambassadors play an important role in trying to accommodate the demands of all parties. They strive to guarantee that groups keep in mind, and respect, the commitments with each other; when needed, they also promote adjustments. To that end, they organize schedules, monitor progress, and prioritize tasks according to interdependencies. An ambassador hinted at the importance of structuring work within a group according to external requests, as follows:

> So what an ambassador should do … if you do not have in mind the product development plan … you might end up being busy with something that is not urgent for the project, so I create schedules, assign tasks, prioritize, shuffle resources, etc. paying attention to the demands from others groups.

The degree to which ambassadors are involved with task management varies across groups due to many factors including the leadership style of supervisors. The general idea, however, is that the sustained contact of ambassadors with various areas and their more outward-facing perspective makes them suitable for the job.

The adjusting work of ambassadors is particularly visible in the ways they coordinate the information exchanges made through the knowledge sharing registry (see Chapter 6). Ambassadors not only represent their groups in the negotiations related to these knowledge exchanges; they also organize activities and review progress within their sections so that it all fits, as much as possible, with the demands from fellow groups. In this enterprise, they work together with coordinators who stipulate macro schedules, while ambassadors plan and review task progression (this will be discussed more in the next section). Consider as an illustration the notes I made in a task planning/review meeting led by a drafter ambassador.

> [The ambassador sits at the corner of a long table by a computer connected to a large screen. There are circa ten drafters across the room. The ambassador opens up a task management software and plans/reviews the activities of each one].
>
> *Ambassador:* OK, this item. [Reading] "Study for protection from debris ingestion." It is related to a proposal discussed in the last technical meeting that is now going to be presented to the chief engineer. Our task is to study the viability of installing a separator in plane X...
>
> *Drafter:* Do we need to check with the group from plane Y as well? [plane X and Y are from the same family and must have similar configurations; the present group only oversees the design of plane X].
>
> *Ambassador:* Yes. I spoke with [the ambassador] there and decided we would have something finished by the end of this week to share so that they can review it next week … we are presenting it all to the chief engineer in two weeks.
>
> [After this dialogue, the ambassador writes some details in a cell of the task management software and assigns it to a drafter according to the agreed schedule by selecting his name from a list in the system].

The rest of the planning session unfolded in a similar way. During a meeting of approximately one hour, the ambassador reviewed progress and assigned tasks while paying attention to co-dependencies and compromises with other groups. It included work related to technical issues (see above), action items from the zonal analysis, information requests, and standard drafting work. The ambassador tried to make sure that deadlines would be met, explaining their ties to external demands; at times, he provided suggestions on how to deal with fellow experts when the tasks involved interactions with other areas.

Although the impression so far might be that ambassadors only organize the work within their groups according to external demands, they also defend the interests of their constituency. That is, the attention on structuring work according to task interdependencies does not mean accepting any request passively, but making sure that existing agreements are respected. The establishment of such commitments, however, is a horse of a different color — and a site of struggles. Ambassadors contest, for example, whether their groups should be responsible for action items from the zonal analysis and dispute requests they deem to be unfair. They also coach peers on how to defend the interests of their groups. As an example, consider the following interaction between an ambassador and a drafter from the same team.

> *Ambassador:* Well, for this one [an action item from the zonal analysis], you need to sit down with [an engineer] so we can either close it or shift the ownership over to them. We finished our part, if there are functionalities they want to check, they should be the ones responsible for it.
>
> *Drafter:* Apparently [the engineer] needs to re-do some calculations … did she call you?
>
> *Ambassador:* I spoke with her and told her that the difference in size [of the aircraft component] is OK for us, so [the action item] is either up to them or done … that is what you should say as well.

In this interaction, the ambassador instructed the worker to push the ownership back for an action item from the zonal analysis. It was his understanding that the drafting team had completed their share. However, because engineers were still considering some changes in the component, the item was still open. The ambassador therefore made a point: to shift responsibility for it to them. Adjustments in these situations are meant not so much to accommodate requests, but to negotiate responsibilities over an interdependent task.

Offices Not (Only) Roles: Formally Recognized Lateral Leaders

The work of ambassadors reflects what is known as liaisons or more generally as boundary-spanners in the literature (Galbraith 1974, Kaplan et al. 2016, Levina and Vaast 2005, Mohrman 1993). Although scholars often imply that this role is an emergent one, in PlaneCo, the position exists on an official level. It constitutes very much an 'office' in bureaucratic terms (*Amt* in the original Weberian text). Typically selected among mid-career/senior workers (some are technical leaders), the implicit policy seems to be that of endowing with official recognition a representative which is already respected among his or her peers. In essence, they carry out the liaison work that most employees with a reasonable experience would be able to accomplish. Indeed, most workers are somewhat familiar with practices such as connecting peers or adjusting tasks and would be able to occupy the role on an ad-hoc basis. Nevertheless, the existence of an ambassador *office* and the separation it establishes between the person temporarily in the position and the role in itself produces three important implications for the work of these intermediaries.

First, the existence of an office in the company hierarchy makes the role more stable. People may leave, yet the office remains: replacements are usually greeted with comments along the lines of: "so, you are the new [ambassador] from the safety group, right?" Whoever the members of a group might be, the engineering unit workers know that there will be an ambassador to discuss interfaces and negotiate interdependencies with. This facilitates greatly the connecting work which has been previously discussed. Much can change in a project, yet there is always someone who workers can refer to and direct communications at.

Second, belonging to an office means that ambassadors are provided with resources to carry out their work (even though it may seem that all they have is a title). Ambassadors liaise with expert groups one-to-one and in meetings. Hence, they are naturally allowed to use their time to do so. As in the previous example of a junior flight engineering ambassador, this might entail attending meetings for 'relational' purposes, an activity that would be uncommon, to say the least, for an average worker. Besides this, the ambassador's position provides access to a vast quantity of information. As points of contact, they are invited to events, copied in emails, and kept abreast of ongoing issues. This is central for their buffering work: it would be harder to represent experts and filter exchanges with a limited participation in cross-expertise processes and little awareness of the 'external' context.

Third, having an office (and not just a role) means that the official acknowledgment for the liaison work carried out by ambassadors exists. Although this does not automatically translate into personal gains (e.g., higher pay), it provides some recognition among peers towards them. Because the position is widely known in the company, it carries with it a set of assumptions, which are particularly relevant for their work. People in forums are aware that the ambassadors are the ones that may represent groups, negotiate adjustments, and sometimes litigate for them. Similarly, there is a general understanding that since ambassadors are outward-facing and involved in many interactions, they are the appropriate individuals to manage and prioritize tasks.

Coordinators: Official Integrators of the Product Development

Previously, I explored intermediaries who are positioned within groups and who link these groups to other company areas. In the current section I concentrate on the coordinators of the product management team, the intermediaries who occupy a 'higher' position in the lateral hierarchy and who mediate relationships among experts from 'outside' the functional axis. Similar to system integrators/project managers, they orchestrate the activities of specialists (I use the term 'coordinator' to stress the fact that they have both a technical and an administrative mandate) (Gassmann and Zedtwitz 2003, Hodgson and Paton 2016, Lawrence and Lorsch 1967b). Next, I present an overview on coordinators, on their efforts to integrate and govern experts, and I discuss how their position in the organizational structure (i.e., connected-yet-outside from functional groups) is instrumental for their work.

The People Who Make Projects Go On

Coordinators oversee aircraft projects and are accountable to the engineering unit director, to the chief program manager, and to top leaders. Despite considerable responsibilities, their authority over functional groups is limited: their role is less of one of direct control, and more of one of consolidating information, of getting (functional) workers on the same page, and of pushing them according to project demands (deadlines especially). Most coordinators are engineers or drafters themselves; they match an understanding for technical aspects of the product development and familiarity with basic administrative tools (e.g., planning).

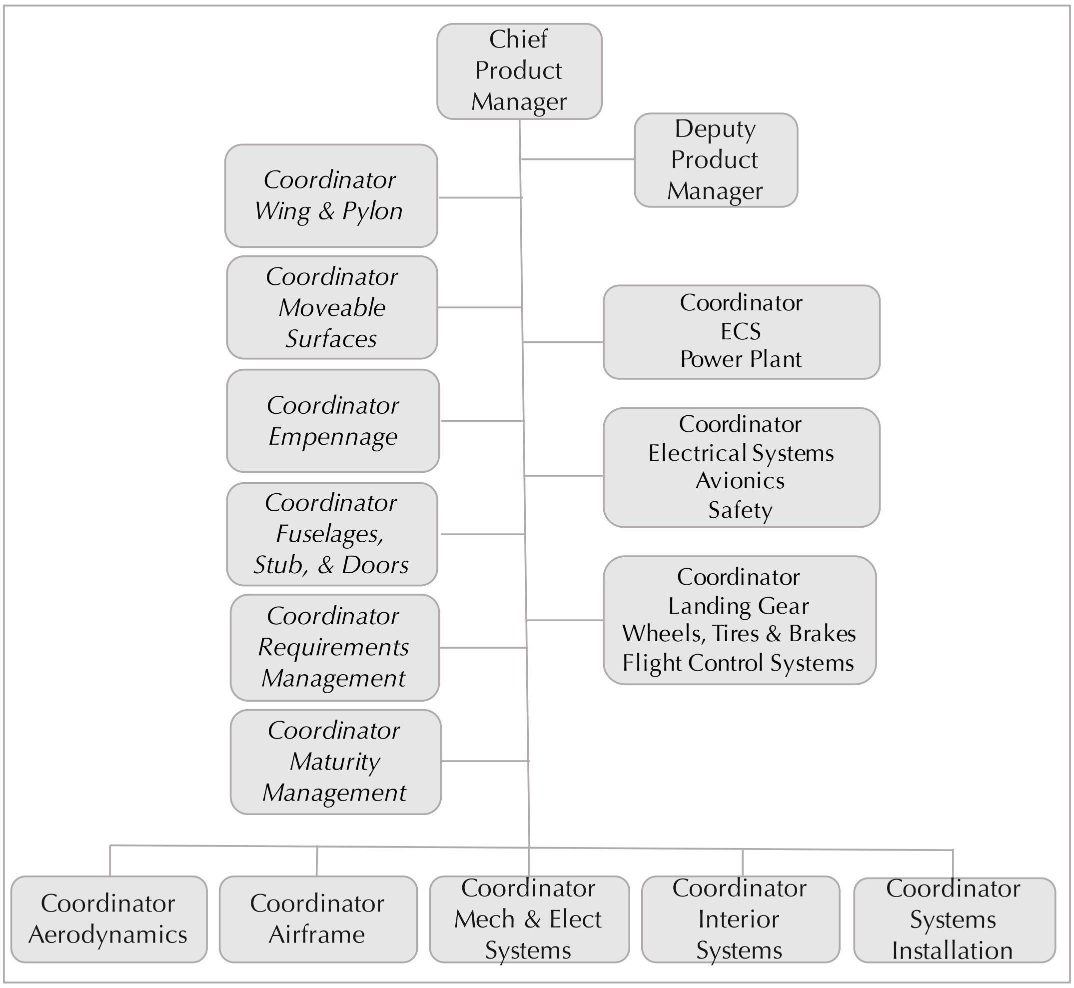
They also combine specialist and generalist competencies — a rare mix in PlaneCo. Many told me that they joined the position out of an interest in gaining exposure to a broader universe of the product development. A mid-career coordinator reflected about his training path as follows: "I did not want to specialize in say aerodynamics … what was interesting for me was the product as a whole." In a similar vein, a chief product manager candidly commented that although his current routine was occasionally extenuating, he "could never go back [to his original technical group]" as he would feel such work to be limiting and 'narrow.'

Coordinators of the product management team may be divided into two categories. The first ones mirror the functional organization of the engineering unit in the product team, in other words, they 'direct' the work of departments/groups. They are strongly connected to functional leaders (some sit close to them) and resemble second-order ambassadors (some are ex-members of the groups they coordinate). Their commitment however is towards projects — indeed, coordinators exert pressure on supervisors/managers to follow deadlines and similar project demands.

The second type are coordinators who oversee undertakings which are common to various expert areas. They are the intersection point for specialists from different groups working towards a shared goal and thus of particular interest here. Among these coordinators we find professionals responsible for aircraft sections (e.g., wings) and cross-domain processes (e.g., product certification). The former ones are the most emblematic and they pull together the effort of groups such as structural engineering, airframe drafting, and manufacturing engineering.

Figure 18 (next page) presents the organizational chart of coordinators overseeing a commercial aircraft. It includes a chief product manager, his deputy, and circa fourteen individuals in all sorts of unique arrangements. The coordinators on the right are responsible for the work of small functional groups (e.g., ECS); the ones on the bottom coordinate large departments (e.g., aerodynamics). On the left, and identified in italics, there are the coordinators from the 'second type' described above: these oversee work packages combining multiple areas (e.g., wings). Although this structure might appear to be quite neat, responsibilities are slightly intricate. Some coordinators 'manage' activities which are also under the broader jurisdiction of (more senior) colleagues (e.g., the empennage work package and its coordinator are also under the responsibility of the airframe systems coordinator). Similarly, the individual coordinating the ECS group also reports to the mechanical and electrical systems coordinator.

Figure 18. Org Chart of a Team of Coordinators (reconstructed from field notes)



Moreover, in a minority of projects (not the one represented in the chart above), some coordinators are not exclusive members of the product management team, but they are also accountable to functional leaders from the groups they oversee. Professionals who had worked in such 'dual appointment' complained that it created conflicts of interest. They did not feel authorized (or even comfortable) to demand from functional leaders what they felt was necessary for the success of a project because they were 'officially' subordinate to them. As a coordinator put it, "it was like trying to request something from your boss." Conversely, integrating a team with fellow coordinators was deemed as positive, as it gave them access to more autonomy and resources (this will be discussed in greater detail later).

Jacks-of-all-Trades Between Technical and Administrative Matters

Similar to the case of ambassadors, the career and activities of coordinators have not been thoroughly formalized; their remit is, in reality, a point of contention. All kinds of people, including the coordinators themselves, have different ideas on what their duties are/should be. Reflecting the 'techie' nature of the company, some maintain that coordinators are fundamentally system integrators: they (should) guard interfaces across aircraft systems and components, and review technical decisions by functional groups. Others see them as project managers who (should) concern themselves more with work planning/monitoring, ensuring that projects fit the constraints of scope, time and costs. In practice, coordinators in product teams fit more or less within these two models, and chief product managers are free to structure teams according to their preferences.

Besides general responsibilities, such as managing project schedules and running some meetings (e.g., technical meetings), coordinators do not seem to follow any clear list of tasks. Their work is very much opened-ended: they face a stream of challenges related to the groups/work packages they handle. When I asked a coordinator what his typical day looked like, he responded half-joking, "the only usual thing is that anything could happen." Indeed, shadowing coordinators, I observed them involved in diverse activities. For example, the to-do list of a coordinator responsible for the wings of a commercial aircraft included the following items:

- Finish presentation fuel tank [technical issue]
- Spar 3 [technical issue]
- Schedule meeting about planning [with functional leaders and ambassadors]
- Presentation status wing and pylon — place figures of before and after
- Discuss with [chief product manager] delay in activities due to workforce shortage in the structural engineering group

Interestingly, besides a mix of admin and technical related work, there are general items without any particular task detailed (i.e., spar 3). When I asked this coordinator for clarifications, he explained that he needs to handle pretty much anything that emerges regarding that matter (i.e., a proposed change in the spar 3) to be discussed in an upcoming technical forum.

This jack-of-all-trades attitude is expected by functional and project leaders who see coordinators as the ones responsible for making a project happen (and those who they can point then the finger at when problems emerge, in light of the emphasis on individualized responsibilities in the company). This idea is illustrated in the comment of a chief product manager to a coordinator during a progress review meeting:

> The meeting chair opens a list of pending tasks on the screen. He calls attention to a delayed technical drawing, while pointing to a particular row in a spreadsheet (listing among others deliverables, deadlines, and owners). The coordinator responsible for this explains that it has not been finished yet due to some missing fiscal classification codes in the ERP system which he claims is not under the responsibility of the engineering unit — and thus not under his responsibility either. To that, the chief product manager retorts with a harsh tone, "listen, there is no such a thing; you are the [coordinator] … so it is your job to do anything you can to keep the project going!"

Although coordinators' activities are rather heterogeneous, their effort gravitates towards a clear mission. Similar to ambassadors, they must facilitate lateral relations with the added responsibility of directing distributed activities. While ambassadors have an operational role, coordinators occupy a more tactical position (e.g., ambassadors plan/review task progression within groups while coordinators pay attention to the overall status of project schedules). In the next sections, I discuss the work of coordinators in integrating specialists around product development activities and governing them.

Integrating Specialists Around Cross-Domain Processes

Coordinators facilitate information exchanges among experts and act as hubs to bring them together. Fundamentally, they are the ones who workers (including ambassadors) look for when they need to discuss matters with a systemic nature or which may impact key project aspects (e.g., costs). As a coordinator put it during an interview:

> The perspective of workers [from functional groups] is naturally limited, it is not a fault, ok? If they were not specialists, they would not be good at their job … but because of this, sometimes they have problems when solving a multidisciplinary issue by themselves … so they end up coming after [coordinators] for help.

According to this informant, coordinators balance out the perspective of specialists as they have a more holistic understanding and are thus better equipped to handle problems featuring complex interdependencies.

The integration work of coordinators is particularly visible in two situations. First, when they connect a wide variety of experts around cross-domain matters. The most common — and intricate — are the so-called "technical issues" which are analyzed and reviewed through a dedicated process (see technical meetings in Chapter 5). Coordinators are the gatekeepers for these technical discussions, integrating information (e.g., calculation results) from all relevant specialists and making sure that their concerns and demands are attended to (a practice also known as "aligning" or "incorporating viewpoints" from specialists, see Chapter 5). During my days shadowing coordinators, I observed that they represented powerful integrative forces: they were busy visiting and calling workers (including ambassadors and fellow coordinators), organizing and attending meetings, and avidly emailing experts to make sure that everyone was "into the loop." The vignette below illustrates this integration effort in relation to a technical issue:

> It is three o' clock when X [senior coordinator] goes to speak with Y [junior coordinator directing groups under the overall responsibility of X]. He mentions an upcoming technical meeting and asks whether Y is coming to it. Y declines the invitation but says that, on his part, he is meeting with suppliers on the next days "to make sure that all is aligned."
>
> X then lists the workers he has been liaising with and who are coming to the meeting; they include another coordinator and some ambassadors from the drafting and manufacturing groups. X and Y then check whether they have information on possible cost and weight increases and whether there is any risk of an impact on the specified requirements.
>
> Y then opens a PowerPoint presentation listing this information (in a checklist) for the proposed solutions to the issue. X replies that it seems that Y has it all covered and suggests that he includes more details for each proposal. They agreed that once they have conducted their separate meetings, they will present the overall situation in a technical meeting to the chief product manager in the next weeks.

As the vignette suggests, coordinators struggle to pull together a wide range of specialists around emerging issues. In the case above, two coordinators had a genuine 'battle plan' to assemble all the necessary information (including that required by a decision checklist discussed in Chapter 5) and to make sure that experts were aware of the issue/in sync before presenting it to the chief product manager.

The second case in which coordinators ostensibly integrate workers is exclusive to those responsible for undertakings spanning various groups (e.g., wing coordinators). These professionals work continually as a living intersection for the multiple specialists working towards a common goal (e.g., drafters and product engineers creating the structural design of a wing). Unlike the previous situation in which coordinators actively seek specialists affected by a technical issue, here the integration work is more continuous: experts chase coordinators as much as coordinators go after them. This is hardly surprising. In a functional organizational structure with interdependent tasks, appointing people as representatives of a cross-domain undertakings makes them the 'natural' go-to individuals. When people think of an aircraft section (e.g., wing) or a general process (e.g., requirements management), they usually think of someone.

This became apparent to me for the first time when a coordinator interrupted a conversation I was having with a senior drafter to inquire about some technical drawings. When I asked the drafter who that person was, he commented while pointing at him, "that young man is the one responsible for the wings of [a plane] … those that I was telling you will be manufactured in [a distant site]." Some weeks later, I shadowed this same coordinator and I had the chance to confirm how much he represented 'the wings' for all practical purposes at any time and in any place he went to. People with a variety of tribulations would come up to him who, in turn, was responsible for getting them up to speed on project matters, and to connect with the appropriate individuals to sort issues out.

Although the integration work of these coordinators might appear effortless, they do labor to pull specialists together. They sit close to the groups they oversee, they interact continuously with their representatives (ambassadors), they set up periodic meetings to check that all parties are progressing in sync, and they handle interface problems which are thrown at them. For example, I eventually shadowed that young wing coordinator which has been mentioned above. Just within the first hours of the morning, he gave an announcement (standing up in the middle of a large room) to experts on the status of the wing work package; he searched for ambassadors and coordinators to discuss a problem in the production of a test plane and to ensure that they would honor previous agreements regarding the delivery of some information; and he chaired a meeting he had organized in which ambassadors from manufacturing and drafting groups reported on the status of some activities.

Governing Horizontal Product Development Processes

So far I have explored how coordinators connect and integrate specialists and their outputs. But the work of these professionals also has a control dimension. They govern cross-domain processes as much as they facilitate them. While distributing information and bringing experts together are both responsibilities that coordinators share with ambassadors (and functional leaders), governing these processes is an attribution which is more distinctive to them alone. The fact that their position is 'overlaid' on functional groups, combined with their direct involvement in many aspects of the product development, makes them ideal to handle lateral processes. Specialists by definition have a more limited perspective, while coordinators embrace a more systemic view, managing the successful progress of a project (e.g., avoiding time overrun). As a coordinator put in an interview:

> They [specialists] have the duty of executing the engineering work, right? So, it is sometimes hard for them to understand the whole [product development] process … or how a decision [they take] may impact others. So you [coordinator] need to reflect about that on their behalf and organize the work of all parties accordingly.

Similar to what has been said by another coordinator quoted before, this informant sees himself as having the comprehensive view which is necessary to organize the activities of specialists around interdependent processes.

The governance role of coordinators is very much linked to their integration work: they direct specialists while integrating them. As well-connected (and sought after) individuals with the official responsibility over distributed activities, they aim to lead workers while bringing them together. A strategy that became especially evident to me during a meeting I observed to check the progress in the release of technical drawings to production (see Chapter 6). In the session there were coordinators, a senior drafter, and an upset chief product manager. Coordinators attributed the delays to manufacturing engineers requesting alterations after the drawings had already been completed and released. The chief product manager then scolded them loudly, "this shows a clear lack of integration … your role is to manage it and bring the groups involved in the release and approval of these drawings together!" The governance work that coordinators carry out falls within two main areas: working as gatekeepers/organizers of interdependent processes, and monitoring the progress and the alignment of activities in functional groups. I review each one below.

Gatekeepers of Interdependent and Systemic Processes

Coordinators are responsible for organizing project-level and cross-domain operations, including the dynamics discussed in the previous chapters, such as knowledge exchanges and technical discussions (Chapter 5 and 6). They are gatekeepers of these processes, who organize them and make sure they progress according to project timeframes. For example, they are the ones who schedule technical meetings, invite participants, prepare presentations, and run them. Given the structure of the engineering unit, their ownership over such matters is undisputed: most people work within functional departments and are responsible for discrete tasks, thus coordinators 'logically' appear as the appropriate candidates to handle them.

As they bring people together, coordinators check that all relevant specialists have been involved and consider whether alternatives are well-balanced in systemic terms. While observing interactions among coordinators and experts in PlaneCo, I noticed that the former were probing specialist workers on how they had conducted their analysis and on the extent to which they had considered the impact of an issue on the systems designed by fellow experts and on the overall project (see Chapter 5 for more about these practices). The vignette below illustrates this activity by describing the work of a coordinator on a technical issue.

> After lunch, the coordinator opens an email from a member of the program management team. It is linked to a technical issue (with a systemic character) about alternative materials for an engine component (i.e., the rocker arm). The program manager sent a schedule showing how much the project buffer would be consumed in case a change between materials was approved (there is great concern for how a change at this stage of the project could impact deadlines). The coordinator tries to calls the program manager to confirm the involvement of the manufacturing group in this planning (responsible for some tasks detailed in the schedule) before forwarding/presenting it to the chief product manager. He calls twice but is unsuccessful. After the third attempt, he gives up and tells

me in a confessional tone, “I do not like to pass things along without being sure of the involvement of the appropriate parties.” He decides to try again later, before discussing the issue with the chief product manager and other associates.

As the vignette shows, the coordinator does not solely pass information along but he makes a point of checking it thoroughly. His role in the organization of technical discussions is not only clerical; he is the one who centralizes the information around issues and makes sure that it all unfolds according to the requirements for trade-off discussions (in this case, calculating the possible time overrun for a proposed change).

Governance is a bit more challenging in the case of activities that involve various specialists, but that are not directly linked to cross-domain processes. This includes, for example, matters that depend on information which is shared ‘informally’ among groups (i.e., not via the knowledge sharing registry, see Chapter 5). Despite not being directly responsible for such exchanges, coordinators still have to make sure that they do not compromise project progress. To that end, a prevailing strategy is to raise awareness among workers for the highly-interdependent character of work in the engineering unit, which means that the delays of a group may ripple out to others. This strategy is visible in the following interaction:

A worker from the loads and aeroelasticity group, overseen by the coordinator, explains to him that they are waiting on inputs from structural drafters to carry out some analyses. The coordinator suggests that they (himself) talk with a drafting ambassador who he calls immediately.

The coordinator explains to the drafting ambassador that a group of computer fluid dynamics (CFD) specialists is working to mitigate the weight of an aircraft part (currently a priority in the project). Thus, as soon as CFD specialists receive some information from the drafting team, they can run the analysis which will in turn enable the loads group to determine airframe specs more precisely.

The ambassador comments that he is aware of the issue. Still, the coordinator insists on the importance of delivering this information on time and encourages him to get in touch in case any delay is likely to take place. The ambassador confirms that all is progressing according to plans and that he will copy the coordinator on the emails from now on. The coordinator thanks him and asks him also to copy the worker from the loads group.

Before hanging up, the coordinator says that he is trying to “help him help everyone, including himself.” Drawing a circle in the air with his hands while talking, he says that without this information, it is harder to set the dimension of the airframe precisely. And this eventually means more re-designs (which are carried out by structural drafters).

During this interaction, the coordinator is asked to mediate an information exchange; yet he does not have direct oversight over the structural drafting group nor is this exchange captured in any official system (e.g., project schedules, knowledge sharing registry). Thus, he cannot make direct demands to them. Trying a softer approach, he makes the ambassador notes that it is in the best interest of everyone (including drafters themselves) that they share some information sooner rather than later.

Monitoring/Being Accountable for Harmonious Progress in Projects

Another aspect of the governance work that coordinators carry out is given by the monitoring progress of functional groups. The diffused idea in PlaneCo is that due to the complex nature of aircraft product development, there must be a group of people carefully watching over the activities of experts groups to make sure projects — and their work packages — proceed according to plans and in sync. In the words of a coordinator responsible for the certification of an executive jet:

> We are in a critical phase of the project … so there is a natural demand for a coordinator with a systemic focus on the certification [of the executive jet]. Someone that navigates through expert areas to see how deliverables are progressing in light of certification deadlines, that creates monitoring routines, that follows discussions … and when a crisis or problem emerges, sets up meetings to bring specialists together.

As this respondent suggests, the monitoring work of coordinators touches upon all kinds of activities. In general terms, it is accomplished as much indirectly (i.e., "following discussions") as through dedicated events (i.e., "setting up meetings").

For starters, many coordinators work close to the groups they oversee — obviously this is contingent on space constraints and particularly tricky for those responsible for various group — and they make an effort to remain in touch with functional workers, especially ambassadors and leaders. Indeed, I observed coordinators routinely walking around, checking in on people, and trying to get a sense of how work was progressing and whether there were emerging problems. Since coordinators have a limited authority vis-à-vis functional employees, this proximity is a way to gain some (lateral) influence over their activities.

Coordinators also keep records and prepare performance indicators related to the work packages or processes for which they are accountable. These provide the basis for checking commitments (and reminding individuals of them), and reviewing work progress. I recorded an interesting illustration of the role of documentation in monitoring activities while observing a small (and rare) cross-functional team designing the horizontal empennage of an aircraft. Specialists often made jokes about a so-called "folder of discord" kept by a particularly neat coordinator. When I asked for clarifications, the coordinator showed me the folder which contained mostly administrative information about the empennage work package, such as schedules, decision minutes, customary technical details, and standard project metrics (e.g., cost estimative). It provoked jokes because he would routinely open it up in meetings to remind specialists about previous agreements or warn them about current plans. This pushed workers to take in consideration requirements from each other (and the project as a whole), thus triggering negotiations and occasional disagreements.

Finally, coordinators accomplish monitoring by setting up regular progress review meetings. These are usually gatherings in which ambassadors (and sometimes also supervisors) update coordinators on the activities in functional groups and jointly establish priorities and deadlines that ambassadors are expected to enforce (see adjusting work above). A similar expectation applies to coordinators themselves. On their part, they are responsible for aggregating information on project progress and conveying it to others, including top leaders.

For example, program managers, especially when they are close to major milestones (e.g., maiden flight), ask for detailed status reports from coordinators, which in turn are passed along to directors and vice-presidents. This also happens in monitoring meetings similar to the ones between coordinators and ambassadors. In one of these sessions, held by the program management team, a coordinator reported a delay of two weeks due to a logistics problem. A senior program manager then proceeded to thoroughly examine the reasons for the delay, inquiring whether all possible countermeasures had been considered. At one point, apparently satisfied by the answers of the coordinator, she explained, "you know, [coordinator], we need to ask these questions because this is what the directors will ask us." The coordinator replied that he was well-aware and had taken that into consideration when gathering information from functional representatives (i.e., ambassadors).

A Connected-Yet-Separate Position in the Lateral Hierarchy

The previous sections showed that coordinators have an important role in ordering the work of various experts in PlaneCo, especially in light of interdependent processes. While their importance for cross-expertise collaboration may appear intuitive but unrelated to bureaucracy, a closer look reveals how much their integration and governance work intermeshes with bureaucratic dynamics. Coordinators have distinct "spheres of obligation" (i.e., work packages) associated with them; some even cluster multiple groups handling some interdependent matters on their behalf. While an arrangement in which individuals have oversight over others is typical of vertical relations (e.g., leaders supervising functional areas), the case of coordinators represents the application of the same principle in lateral dynamics.

Coordinators are official 'owners' of undertakings and issues in aircraft projects, most of which depend on inputs from various groups. Much like ambassadors, they occupy a bureaucratic "office" (a position in the organizational hierarchy). However, this office is bundled into product management teams positioned laterally on the engineering unit hierarchy, connected-yet-separate from functional areas. While the case of ambassadors showed that occupying an office (not just a role) brings important consequences for the work of intermediaries, the case of coordinators suggests that the position of offices in the organizational hierarchy/structure greatly influences the work they carry out.

First, the hierarchical position of coordinators in product management teams gives them connections to various groups (similar to what happens in configuration control boards, see Chapter 5). By being overlaid over functional areas — sometimes physically in the middle of specialists — and owners of project work packages, coordinators become intersection points. Experts from all areas come to discuss all sorts of issues with them. Besides this, coordinators themselves are a source of contacts. Thus, the fact they are bundled together in the product management team means that they can rely on each other to reach workers and leaders across the board. This relational capital is essential for their integration and governance work, since they need to gather information from various areas and keep abreast of the status of activities.

Second, the position of coordinators in the hierarchy allows them to have some separation from functional groups due to the way in which accountability and resources flow. Product management teams are positioned 'adjacently' to the functional axis of the engineering unit, and are directly linked and responsible to its director. Therefore, despite working closely with functional leaders, they are not accountable to them (see Figure 16 above). This provides coordinators with a more neutral ground vis-à-vis functional groups which is essential for their work which mediates — and sometimes arbitrates — interactions among them, such as when they govern trade-off negotiations in technical meetings (Chapter 5). It is telling that, as mentioned above (page 183), coordinators who had worked as members of both functional departments and product teams considered this as a less-than-ideal arrangement.

Conclusion

In the past sections, I explored the work of ambassadors and coordinators (see Table 7 for a summary). These intermediaries order interactions and exchanges among a variety of experts, pulling together their know-how and outputs, and orchestrating their activities according to interdependencies and project requirements. These activities are all typical of cross-expertise collaboration and widely discussed in studies about mutual adjustment among specialists (Barley, W. 2015, Bruns 2013); integrating roles, such as boundary-spanners, liaisons, and integrators (Kaplan et al. 2016, Lawrence and Lorsch 1967b, Levina and Vaast 2005, Mohrman 1993); and the challenge of recognizing 'who knows what' and enlisting their contribution (Hansen and Nohria 2004, Hansen 2009).

In PlaneCo, bureaucracy plays a significant role in the activities of intermediaries. The existence of an ambassador office gives these professionals the necessary resources to carry out their work and ensures the long-term survival of this liaison role (the office remains while individuals may change). Similarly, coordinators can better accomplish their mandate because they are grouped together in a hierarchical position overlaid over functional departments. It is not that modern scholarship is oblivious to issues such as the access to intermediaries' resources

(Levina and Vaast 2005). Instead, the problem is that the literature overlooks how much bureaucracy exists in processes as elementary as appointing someone to an official position or as the owner of a work package. For example, while ownership is a familiar concept in project management, it is simply a new label of what Weber discussed as the 'spheres of obligations' of an office in the hierarchy.

Bureaucracy has long been associated with (inflexible) vertical relations. As a matter of fact, organization and management scholarship correlates lateral links with 'organic' contexts, which have been traditionally understood as absent of hierarchical structures and offices (Dougherty 2008). Some academics propose that bureaucratic arrangements are antithetical to lateral relations (Boland and Tenkasi, 1995); scholars of integrating roles (e.g., boundary spanners) are oblivious at best to the role of bureaucracy in them (Galbraith 1974, Galbraith and Lawler 1993, Galbraith 1993). Contradicting these assumptions, this chapter has shown that bureaucratic arrangements are not contrary to lateral relations. Quite the opposite, they might be designed to facilitate them.

Table 7. Characteristics of Intermediaries

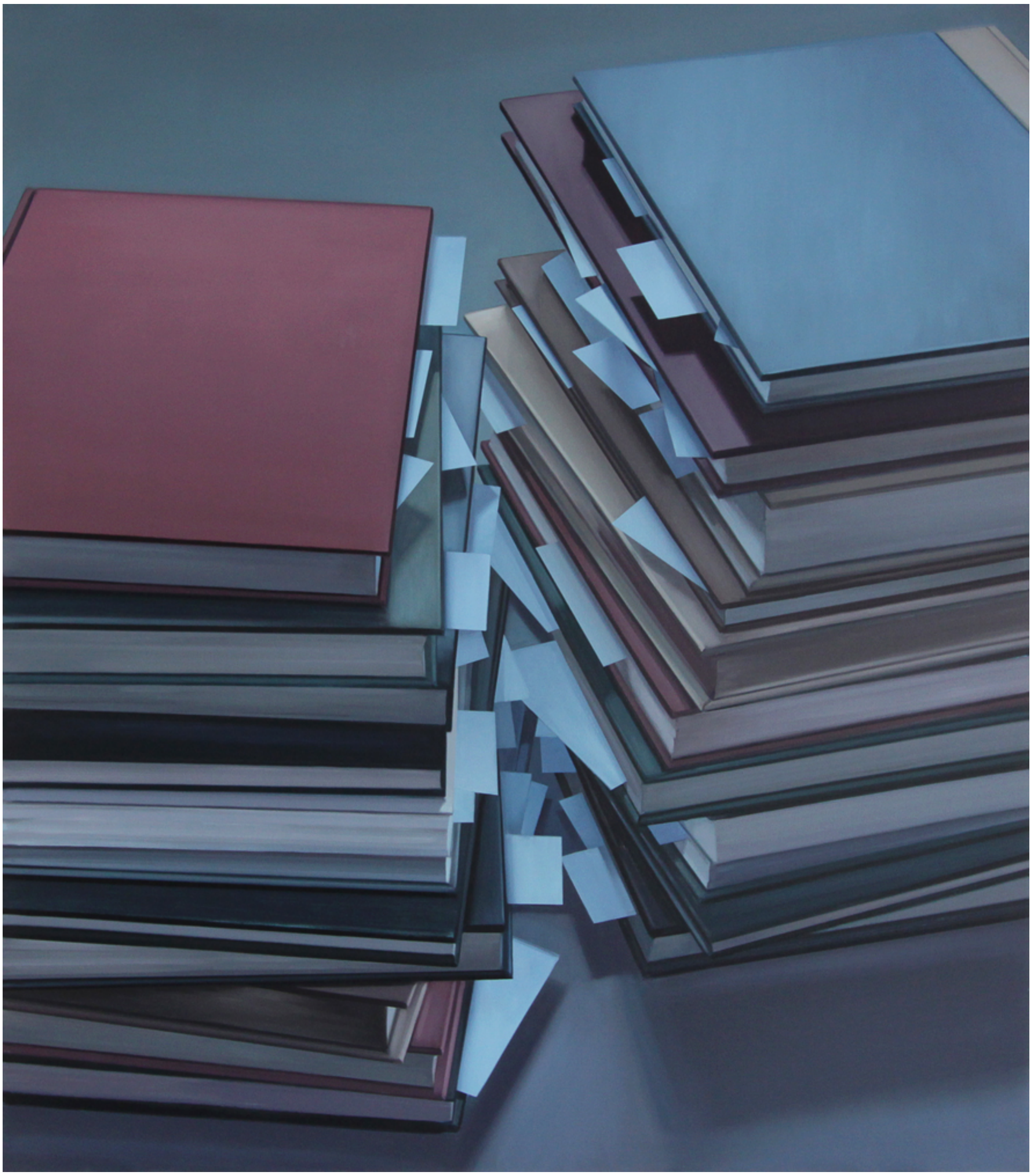
	Ambassadors	***Coordinators***
Main Responsibilities	Represent, lead the resolution of technical issues, and mediate exchanges	Promote alignment, govern cross-domain undertakings, and monitor progress in projects
Profile	Senior and mid-career workers usually with a good technical level	From senior to junior workers with mixed technical levels
Bureaucracy	Office with set responsibilities within functional groups	Office with established responsibilities overlaid in the matrix

CHAPTER 8

DISCUSSION

&

IMPLICATIONS



Carl Hammoud – Untitled (Summit)

Introduction: Taking Stock of Bureaucracy Seriously

The previous three chapters explored the intermesh of bureaucracy and cross-expertise collaboration in PlaneCo. In this final chapter, I review these dynamics on a more theoretical level. I start by providing a recap on how bureaucratic arrangements make relations among experts more unambiguous, calculable, reliable, and precise. With this I address my first research question (How does bureaucracy shape cross-expertise collaboration?). I then summarize my findings into four enabling roles for bureaucracy in cross-expertise collaboration, thus addressing my second research question (What are the possible benefits that bureaucratic arrangements produce to work across expertise domains?). After this, I present some of the characteristics of the bureaucratic arrangements I identify in this thesis, and I provide an overview of some of the conditions underpinning their positive impact in collaboration. I then introduce the contributions of this work to the literature on cross-expertise collaboration, expertise coordination, the study of bureaucracy, and to the general practitioner literature on collaboration. The chapter concludes with a reflection on the limitations of the thesis and the avenues it opens for future research.

Rationalizing Cross-Expertise Collaboration: A Review of the Cases

> *Albert joined PlaneCo a decade ago. He is a product development engineer working on a new commercial aircraft. Today he planned to work on some engineering analyses. However, these depend upon information from another group that is late. <u>So he asks a senior colleague</u>* <u>[an ambassador]</u> *<u>to help him work out when it is likely to be delivered</u>. Later he calls an expert from another area to request some design data. After some back and forth, they agree on a deadline and Albert emails a fellow in the product management team about it* <u>[a coordinator who records it in the knowledge sharing registry]</u>..
> *[…]*
> *Albert checks his to-do list and realizes <u>he owes some time-sensitive information about an aircraft part to a drafter who requested it weeks ago</u>* <u>[via the information collector system</u>. *He knows that sending it late would compromise the release of technical drawings to manufacturing, thus upsetting the production schedule (and putting him in an uncomfortable position).*
> *[…]*
> *A member of the product management team calls Albert. He says that a technical solution proposed by some peers may impact the system overseen by his group. Thus, they ought to do some studies and report whether any*

> *significant alteration is likely to be needed. Albert agrees to share their position on the matter within a week so he can incorporate it into his presentation to the chief engineer.*
>
> *[…]*
>
> *A colleague from his group then surprises Albert, asking him to step in for him in a cross-domain meeting. He is a bit reticent at first, but his colleague insists: he was summoned last minute to go to a conference call with suppliers and someone from the group needs to attend the other meeting* [the zonal analysis]. *Albert agrees. He goes to the gathering where he finds representatives from most of the engineering unit areas and signs an attendance list on behalf of his colleague.*
>
> *[…]*
>
> *Albert and colleagues attend a progress review session led by a senior member of the group. While checking advancements and assigning new activities to each one of them, the leading worker* [an ambassador] *stresses that some deliverables are priorities — due to interdependencies or because they had been highlighted as time-sensitive.*

This same vignette appeared in the first chapter of this thesis as an illustration of the cross-expertise work in PlaneCo. As I have previously discussed, it shows the everyday routine of Albert, a generic product development engineer busy requesting/delivering information to different groups; discussing technical issues that depend on the expert judgment of various workers (himself included); interfacing with a multitude of specialists; and adjusting his work according to interdependencies. While all this may appear on the surface to be unrelated to bureaucracy, the previous chapters shed light on the ways in which these collaboration processes are rationalized in PlaneCo. I will now go over this argument by using the vignette above as the basis from which to consider the silent-yet-effective influence of bureaucracy in cross-expertise collaboration (I take the underlined parts to be the ones in which this is the most visible).

First, bureaucracy regulates cross-domain meetings (see Chapter 5). In PlaneCo, a multitude of workers from different groups must pull their expertise together to problem-solve, review technical proposals, analyze the potential ripples effects of design changes, and overall reach appropriate engineering solutions. This is visible in the second and third paragraphs of the vignette which show X debating an ongoing technical issue and attending a cross-domain meeting on behalf of a colleague. Bureaucracy is present in these processes to the extent that there are specific procedures which bring the relevant experts together and keep them abreast of systemic issues. These include sign-in sheets and metrics to keep track of attendance (e.g., zonal analysis) as well as checkpoints to ensure that the expert groups which are impacted by an issue are aware of it and aligned with regard to it (e.g., configuration control). In addition, workers appointed into specific offices (e.g., coordinators) govern cross-domain meetings, monitoring that all relevant groups adequately put forward their viewpoints and sustaining well-rounded systemic solutions over parochial interests.

Without bureaucracy, participation in these processes would be potentially much more erratic. Certainly, experts believe that going to meetings is important at any rate, and they would be able to casually work out interdependencies. Still, without standard procedures there is less certainty on (and control over) whether the relevant specialists are present in gatherings and whether they are able to express their views on a given matter; there are also no mechanisms to check whether decisions privilege systemic solutions. Cross-domain events would probably be held according to emerging needs, possibly without a definite periodicity and governance mode. Interestingly, according to oral accounts and publications about the company's history, some important gatherings were run in an erratic manner in the past, including the technical meetings (see the vignette that opens Chapter 5).

Second, bureaucracy formalizes the circulation of information (see Chapter 6). As shown in the first two snippets of the vignette above, in order to accomplish his work, Albert depends on many knowledge exchanges. He is continually requesting/delivering drawings, reports, calculations results, etc. from/to different groups within tight deadlines. Bureaucracy exists in these relations to the extent in which workers use formalized channels for information sharing. In this way, details about exchanges are recorded in an objective manner into databases (e.g., due dates). While talk may be cheap, having your promises written down in an official register pushes experts to live up to them. Not least because writing them down makes it easier to manage them and to see to them being respected.

All this would unfold in a significantly different manner were bureaucracy nonexistent. Agreements regarding knowledge exchanges would be established verbally without any official record of them. Thus, it would be more challenging to review and make sure that information exchanges unfold appropriately, and there would be no objective evidence of agreements to adjudicate disputes or prevent abuses by higher status groups from taking place. Some of these situations were indeed present in PlaneCo and represented the reason behind the bureaucratization of knowledge exchanges (see Chapter 6). For example, drafters would not get the inputs they needed from engineers in a timely manner and they would be blamed for delay; this is what motivated the creation of the information collector tool (see Chapter 6).

Third, bureaucracy establishes formal positions for intermediaries in the lateral hierarchy (see Chapter 7). As illustrated in the vignette above, intermediaries liaise negotiations between X and colleagues, involving him in technical issues, and leading the prioritization of activities in light of interdependencies among groups. Thanks to bureaucracy, these intermediaries occupy precise offices within the organization structure which gives them resources to carry out their work — they are not ad-hoc roles that random professionals take up.

Although intermediaries exist independently of formal offices, such bureaucratization has noticeable consequences. Without it, there is no certainty as to whether the role endures once particular workers leave the company or simply give up on it. Also, experts would probably adjust activities and negotiate issues by themselves, without appointed workers governing cross-domain processes and work tasks. According to informants, at the dawn of the matrix structure in the engineering unit, the integrator position was more of an improvised, ad-hoc one. With time, some primary characteristics of an office — which always existed for vertical functions — emerged for lateral positions as well.

All this indicates that bureaucracy shapes cross-expertise collaboration in PlaneCo in a significant manner (see Table 8 for a summary). Bureaucracy is an engine for the reduction of uncertainty; it makes collaboration dynamics more calculable, precise, reliable, and unambiguous (Gajduschek 2003). As I showed in the previous chapters, and summarized here, bureaucracy regulates work related to systemic issues and interdependent processes according to objective and predetermined procedures. It makes information exchanges among experts more impersonal and governable. It provides certainty around the existence of intermediaries ordering interactions and leading adjustments among experts. Following Leigh Star and colleagues, we may thus consider bureaucracy as an infrastructure for collaboration (Star 1999, Star and Ruhleder 1996). In the next section, I explore in detail the key ways in which bureaucracy enables cross-expertise collaboration.

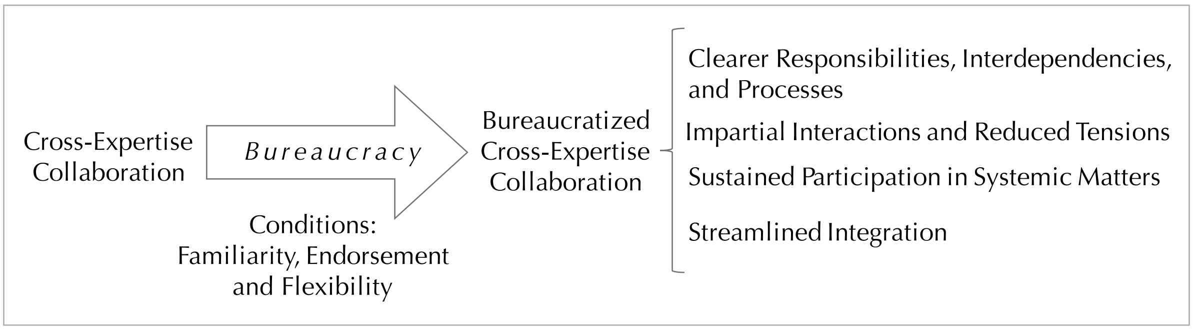
Table 8. Summary of Bureaucracy & Cross-Expertise Collaboration

	Without Bureaucracy	***With Bureaucracy***
Cross-Domain Meetings	Meetings are scheduled according to emerging needs; there is no set agenda.	Meetings are routinized and follow various formal procedures.
	Participation in meetings is optional — or just not recorded nor regulated. There is no requirement or at least no objective mechanisms to control that experts are kept abreast of cross-domain/systemic issues.	There are procedures regulating invitation/attendance in gatherings (attendance is not optional) and demanding that the relevant experts be informed and express their viewpoints on cross-domain or systemic issues.
Knowledge Exchanges	Agreements about information sharing exist only verbally (informally) or in ad-hoc personal records, e.g., emails. There are no objective/centralized records.	There are objective records of agreements making up centralized lists of exchanges visible to all workers.
	Workers sort out arrangements among themselves, based on personal initiatives. There is no appointed individual or mechanism to enforce agreements or mediate negotiations.	Exchanges are reviewed by appointed employees through monitoring routines in which specific experts are held accountable and pushed to honor agreements.
Intermediaries	Workers take up the function of intermediaries in an ad-hoc manner. There is no certainty about their continuity, who performs it, and whether they have the resources to do so.	Intermediaries are formalized as offices which provide them with the necessary resources and establish a single point of contact for groups (ambassador) and clear owners for project matters (coordinators).
	Expert groups adjust interdependent activities by themselves (such as establishing priorities). There is no official governance over these coordination processes.	Interdependencies are worked out, prioritized, and adjusted according to monitoring routines carried out by individuals occupying the specific office.

Enabling Roles of Bureaucracy for Cross-Expertise Collaboration

In the previous section, I proposed that bureaucracy rationalizes cross-expertise collaboration. Here I explore this idea further. Harnessing the empirical material presented in the previous chapters, I detail some of the enabling roles of bureaucracy for cross-expertise collaboration: clarifying responsibilities, interconnections, and complex processes; promoting impartial interactions and reducing tensions; ensuring participation in systemic matters; and streamlining integration (see Figure 19 for a summary).

Figure 19. The Enabling Roles of Bureaucracy



Bureaucracy Clarifies Responsibilities, Interdependencies, and Complex Processes

The collaborative work of specialists hinges on their ability to comprehend their position in the work processes they are involved in (Hansen and Nohria 2004, Hansen 2009, Tuertscher et al. 2014). This "situational awareness" is of particular importance in complex settings such as aircraft product development. My fieldwork shows that bureaucracy helps to clarify the work context of experts in three ways.

First, bureaucracy makes responsibilities clearer. This is no minor feat. When tasks depend on the joint work of various individuals, there is the risk of ambiguous accountability (see Darley and Latane 1968 on the diffusion of responsibility). As the adage goes, when everyone is responsible, nobody is responsible — or everyone always thinks that someone else is in charge. Many bureaucratic mechanisms foster clear responsibilities in PlaneCo. The most noticeable is the very organization structure of the engineering unit. Functional departments have the upper hand which means that workers are highly-specialized and work packages are broken down as much as possible according to distinct expert groups. Also, there is a deep-rooted attention for individualized responsibilities. Unlike in a Kafkaesque universe, tasks, issues, and processes — intricate as they may be — usually have the name of an 'owner' attached to them. Consider the case of the zonal analysis: even when an activity involves many interdependencies, the chairman assigns it via an action item to individual experts/groups. By the same token, the oversight of cross-domain processes is entrusted to particular workers (i.e., coordinators). They 'own' knotty sub-projects and are the gatekeepers of systemic issues even though it may all depend on a multitude of experts. Thus, when workers need to discuss emerging matters involving numerous areas, they know who they can go to; and when leaders have demands or require updates, they can direct them to someone in particular.

Second, bureaucracy simplifies interdependencies. This is partly related to the establishment of clear responsibilities. To have clear accountabilities helps to explicate "who does what" in joint undertakings — an essential aspect of collaboration (Hansen 2009). Just because interdependencies are complex, they do not need to be complicated. With well-defined accountabilities, experts can more easily identify the person responsible for a given task amidst interconnected activities while managers gain visibility over the progress of undertakings that depend on a myriad of interrelated tasks. Also, a whole host of formalizations helps employees in the engineering unit navigate co-dependencies, such as ambassadors and the knowledge sharing registry. Regarding the former, the existence of an "office" (not only a role) means that there is always someone in an expert group that you can contact to request information, invite to meetings, ask for a viewpoint, or negotiate adjustments. As for the latter, one of its advantages is that it makes all the information that experts and their groups are expected to receive explicit and it provides them with this information at a certain point in time.

Third, bureaucracy clarifies complex processes (of which there is no shortage in aeronautical product development). Again, clearer responsibilities and interdependencies are a first step to help experts realize which is their share in distributed processes. By understanding their tasks and their connections, they gain a more holistic perspective about their work. Moreover, the systematized and codified nature of product development helps workers to find their way around it. The many project phases, milestones, and routines are easily identifiable and documented in guidelines accessible by workers in an electronic database. Thus, if employees need to know details of processes to handle a particular matter in a given phase (e.g., proposing design changes), they can check it on the product development manual. Bureaucracy also makes product development activities unfold in a routinized manner, while providing clarity over which issues are handled when, where, and how. For example, each aircraft project has a standing agenda of meetings happening every week on the same days, at the same place, and time; this helps specialists orient themselves in the complex environment of PlaneCo with numerous parallel activities.

Fostering clarity is a positive aspect of bureaucracy which is usually discussed in the literature — although "bureaucracy" sometimes appears under another name (e.g., structure) (Bunderson and Boumgarden 2010, Kessler et al. 2016, Valentine and Edmondson 2015). Scholars stress the fact that well-designed 'structures' or 'processes' facilitate cross-expertise collaboration (and innovation more generally) to the extent that they establish clear roles, priorities, and relations of authority for specialists (Dougherty 2008). My findings very much corroborate these insights from previous researchers.

Bureaucracy Promotes Impartial Relations and Reduces Tensions

The established literature has extensively documented struggles and conflict in work across expertise domains (Carlile 2002, Barley, W. et al. 2012, Contu 2014, Levina and Orlikowski 2009). Sometimes, prestigious specialists impose their own demands and perspectives, while groups with a lower status struggle to be heard or to gain access to cross-disciplinary forums/integration processes (Oborn and Dawson 2010, Contu and Willmott 2003, Manias and Street 2001, O'Brien et al. 2009). Even those mechanisms which have been set up to integrate the work of various specialists, such as multidisciplinary teams, may re-create barriers (Liberati et al. 2016). Countering this point, another aspect of bureaucracy highlighted by my fieldwork refers to its role in promoting impartial interactions among experts and thus reducing tensions. This does not mean that bureaucracy makes relations peaceful or that conflict is inexistent. Instead, the key point here is that bureaucracy is put in place to ensure that exchanges unfold against a backdrop of clear expectations, that agreements are respected, and that disputes are handled by a third party. In brief, that they follow objective principles that make relations more impartial.

First, on a general level, bureaucracy fosters impartial relations by establishing specific processes and routines for experts to interact with each other (see point above on clarity in complex processes). Therefore, experts know, for example, that certain undertakings belong to different phases and that systemic issues are discussed in specific forums and must be evaluated by specific groups. This sets expectations for employees on how to go about working and interfacing with each other, as there are general rules and procedures regulating interactions.

Second, bureaucracy provides a contract-like dimension to relations. Expert groups are continually exchanging knowledge in PlaneCo. Bureaucratizing these knowledge flows makes information requests and related agreements more objective and binding. Consider the case of the knowledge sharing registry. Putting details about agreements in writing makes it possible to entrust a third-party to check that experts live up to their promises. Making sure that arrangements are more than empty promises is particularly relevant in the case of interdependent work between experts from different levels of status. Without any clear documentation, responsibility for problems may become erratic which usually means that the weakest goes to the wall. This was the case before of the drafters who then implemented a formal system used to show when delays in the release of drawings for production are due to missing/delayed information from engineers.

Naturally, despite these bureaucratic mechanisms introduced to smooth relations, conflicts nevertheless emerge. Under these circumstances, bureaucracy still plays an important role by providing instruments to arbitrate disputes thus easing the strain from negotiations. For example, communication standards are used by drafters to embed information on drawings (e.g., where to position the holes for cables in an airframe part); and when there are breaches on what was agreed, placeholder drawings serve as an external record of an arrangement, showcasing exactly what the breach was. Moreover, part of the job description of individuals occupying intermediary offices (e.g., coordinators) includes arbitrating conflicts among experts. As third-parties unaffiliated to functional groups, they have the legitimacy — on top of the formal power — to settle discords. For example, the chief product manager is responsible for sorting quarrels about the (re)scheduling of information exchanges in the knowledge sharing registry, as well as those about competing solutions in technical meetings.

The role of bureaucracy in promoting harmonious interactions has partly been discussed in the literature. There are general discussions on the societal value of bureaucracy as an impartial and fair system (Gay 2000) and on the importance of rules in establishing clear expectations and an objective backdrop to fall upon in the case of conflicts — although these scholars do not necessarily focus on cross-expertise work (Crozier, 2010 [1964]). The ability of bureaucracy to smooth relations and solve conflicts in organizations is also associated with the settling of disputes by top leaders (Leach 2015, Levina and Orlikowski 2009, Fjeldstad et al. 2012, O'Mahony and Ferraro 2007). Nevertheless, the literature seems to overlook the importance of the mundane aspects of bureaucracy in these dynamics, such as the role of records in cementing agreements and thus making relations more impartial. My findings, therefore, call attention to the fact that bureaucracy promotes fairness and eases tensions not only by settling disputes through the intervention of formal leaders, but also by dressing relations up with a contract-like quality and by establishing impartial transaction channels.

Bureaucracy Ensures Sustained Participation in Systemic Matters

Many procedures, routines, and offices in PlaneCo are engineered to ensure an adequate participation of experts in systemic processes (e.g., technical meetings), and in decisions with ripple effects (e.g., CCB). While this is partially due to the systemic nature of aeronautical product development (see Chapter 4), working out the integration of specific activities and outputs is an intrinsic challenge in any interdependent work process (Okhuysen and Bechky 2009).

Bureaucracy ensures the participation of experts by providing quite literally a seat at the table. In other words, the presence of the appropriate individuals in gatherings and processes does not boil down to a matter of will. It is regulated by procedures. For example, certain cross-domain meetings have control systems for attendance in order to register and keep track of the presence of representatives from expert areas (e.g., zonal analysis). In other events which fall under a more soft-regulation regime, this is done directly by the chairpersons and project leaders, who check that the relevant experts are present in meetings and when necessary summon them on the go (e.g., CCB).

Besides guaranteeing the physical presence of specialists, bureaucratic arrangements also give them the space to voice their concerns and perspectives. For example, protocols demand experts to incorporate the inputs of all groups impacted by a technical solution; this is then regulated by appointed individuals (e.g., coordinators from the product management team). In the case of particularly delicate processes (e.g., configuration control), there is a checkpoint to guarantee that a decision incorporates the inputs (e.g., constraints, analysis, requirements) of all the areas impacted by it.

The capacity of some of these mechanisms (e.g., intermediaries) to promote and enforce participation has already been identified by previous authors who have explored the role of formal organizational elements in lateral relations (Galbraith 1974, Mintzberg 1980). However, they seldom consider their bureaucratic dimension. For example, in PlaneCo, liaison professionals occupy an 'office', whereas in most of the literature they are 'simply' specialists who have been either appointed ad-hoc or who take up such role in an emergent manner. I posit that it is precisely the intermesh with bureaucracy that makes such mechanisms capable of ensuring that relations and exchanges progress appropriately. Bureaucracy creates a sort of integration control: procedures and appointed individuals regulate whether decisions 'integrate' the contributions of various experts.

Bureaucracy Streamlines Integration

Expanding on the previous point, we can say that while bureaucracy ensures participation and integration, it does not achieve it randomly. Procedures, routines, and offices are engineered to bring experts together at precise moments and through specific channels in PlaneCo. Despite the high level of reciprocal interdependence in the engineering unit cross-expertise relations are designed to unfold in a 'focalized' manner. This does not mean, however, that experts are not continually interacting. Of course, they are. The point here is that work is structured to preserve functional specialization and individual responsibilities with specific mechanisms which handle integration — an alternative configuration would be a more team-based one (Altfeld 2010). Figure 20 provides a schematic illustration of the main aspects of these 'focalized' cross-expertise relations.

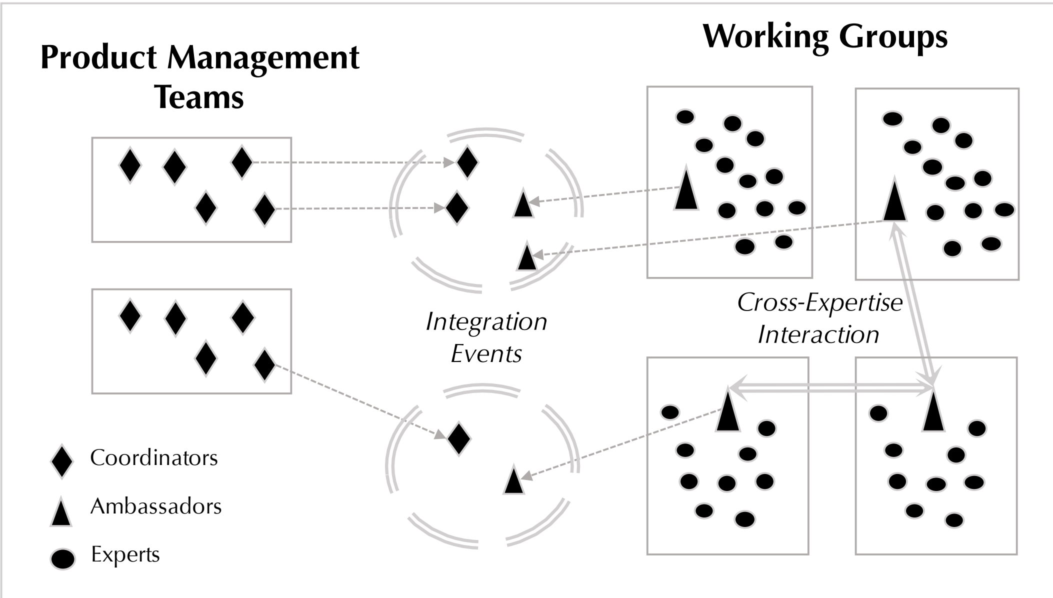
First, bureaucracy streamlines integration by bringing experts together to deal with interfaces, systemic matters, and cross-domain processes in specifically orchestrated situations (see integration events in Figure 20). For example, despite astronomical interdependencies, drafters and engineers specialize in different aircraft systems/components and work in separate functional groups (not according to aircraft zones or major functionalities as it is common in some aeronautical companies). While they are continually negotiating co-dependencies, the most intricate ones are usually discussed in certain routinized forums. Technical meetings along with the zonal analysis ones, for example, are temporary-yet-structured integration events; they allow for an alignment around issues that involve many experts in a circumscribed and standard manner.

Second, bureaucracy streamlines integration by limiting the number of those who ought to take part in cross-domain events (see Figure 20). The workers involved in them are usually coordinators and ambassadors representing different groups (and occasionally supervisors and managers). Thus, experts (and functional leaders) can progress with their activities undisturbed. By the same token, while the complex interdependencies of product development require exchanges among various expert areas, this does not mean that all specialists need to interact. Ambassadors are responsible for liaising across groups (see 'cross-expertise interaction' in Figure 19). In addition, they meet 'laterally' with integrators, in a sort of microcosm, to make sure that all those involved in a joint undertaking progress in sync. Thus, activities linked to cross-expertise relations (e.g., contacting experts, gathering information) are absorbed by individuals with the resources to carry them out.

This streamlining effort has the advantage of making collaboration more 'economical' — a theme which is usually ignored by the literature, except for studies with an information processing/organizational economics orientation (Argyres 1999, Gerwin and Barrowman 2002). It reduces coordination costs (Adler 1995, Sherman and Keller 2011, Tushman and Nadler 1978) and helps to deal with complexity and collaboration overload (Gardner 2016, Cross et al. 2016, Cross 2013, Cross et al.

2008). Experts do not need to worry about interdependencies continually; they have a system to reach out to each other and to integrate their work (for an example of individuals synchronizing activities without extensive exchanges of information see Argyres 1999). Metaphorically, we could say that while experts live in a 'province of knowledge,' they are quite aware of the hubs which are available (e.g., intermediaries); while lacking a direct connection to fellow experts, they can easily reach an operator (e.g., ambassador) who may put them in touch with their counterparts in other expertise areas.

Figure 20. Visual Representation of 'Focalized' Integration



This endorses the idea that collaboration is about the right balance of specialization and functional work, as well as about sharedness and integration (Bruns 2013, Mengis et al. 2013). Although usually forgotten, specialization is an important aspect of cross-expertise collaboration, especially in complex environments. It allows workers to ignore most of the information which is not directly relevant to their activities, and to only worry about interdependencies in particular situations (Ben-Menahem et al. 2016, Postrel 2002, Leonard et al. 2011).

And yet most of the scholarship on work across expertise domains highlights the importance of unity (e.g., common ground) and tightly-integrated work arrangements (e.g., cross-functional teams), especially in situations of reciprocal interdependence (Barley, W. 2015, Bruns 2013, Thompson, J. D. 1967, Hoopes and

Postrel 1999, Mengis et al. 2013). The overall assumption is that experts must nurture deep familiarity with each other and work in teams (Brown and Eisenhardt 1995, Edmonson and Nembhard 2009, Holland et al. 2000). In contrast to that, my findings highlight a context in which experts come together in precise moments and through specific channels — satisfying integration requirements, while continuing to work apart — thanks to bureaucracy (see Bruns 2013 for a similar work arrangement in scientific laboratories). This raises doubts concerning the idea that reciprocally interdependent activities demand supplementing specialized structures in favor of cross-functional ones (this will be discussed further in the section devoted to practical implications)

Some Characteristics of Bureaucracy in PlaneCo

In the earlier sections, I explored the intermesh between bureaucracy and cross-expertise collaboration. In this section, I focus, instead, on the specific characteristics of bureaucracy in PlaneCo. More specifically, I unpack its key features and present which conditions underpin its enabling effects in collaboration, as described previously. As I will explain, the bureaucratic arrangements I identified in PlaneCo have a positive impact on collaboration to the extent in which workers are familiar with them, endorse them, and may deal with them in a flexible manner. I argue that while all this makes bureaucracy in PlaneCo appear to be unique, it is all actually part of a traditional process of work rationalization (Weber 1978, Albrow 1970).

The Locus of Bureaucracy

When speaking of bureaucracy, organizational scholars rarely pause to consider what exactly is bureaucratized in a given context and how the rationalization process takes place (Kallinikos 2011, Robertson, M. and Swan 2004, Sturdy et al. 2014). Bureaucracy usually appears as a ready-made 'thing' implemented in organizations across-the-board. As we have seen in the previous chapters, however, bureaucratization does not necessarily spread evenly: it may well concentrate on precise work processes and not on others. Nor is bureaucracy a closed list of elements, contrary to the belief of many scholars who insist on using the Weberian ideal-type or related templates as a 'measure' for bureaucracy (see for a critique Clegg and Lounsbury 2009). Thus, when speaking of bureaucracy, we must consider its precise locus and the specific elements that make it up.

The bureaucratic arrangements explored in this thesis are linked to a large degree to lateral processes. This might appear to be slightly paradoxical, as the literature on bureaucracy does not discuss (the regulation of) lateral relations much (Landsberger 1961, Dahlander and O'Mahony 2011). The focus lies usually on the formalization and control of individual behavior and task execution (Taylor 1911, Huising 2014). Contrary to that, the bureaucratic arrangements presented in the previous chapter target the ways in which workers come together, inputs and outputs circulate, and work progress is governed.

In other words, the bureaucratic mechanisms described previously formalize the exchanges among experts, and not so much their individual work (e.g., knowledge sharing registry); they control the participation of experts in meetings, and less their behavior in them (e.g., zonal analysis); they establish requirements for technical proposals, while leaving specialists to be reasonably autonomous on how to reach them (e.g., configuration control); they place workers in offices with clear responsibilities over the integration of work, but without forcing them to follow a set list of tasks (e.g., ambassador's office). Thus, this thesis shows that bureaucracy is not antithetical to lateral processes and can even be beneficial to them. In other words, official roles and formal channels may make horizontal relations unfold smoothly in the same way as it is assumed that they do with vertical relations (Blau 1973).

Conditions Influencing Bureaucracy

I have shown that bureaucracy has an enabling impact on cross-expertise collaboration in PlaneCo. However, this does not only depend on its characteristics but also on the conditions in which bureaucratization takes place. As extensively documented by scholars of technology in organizations, any element that (re)structures work may lead to multiple outcomes (Adler and Borys 1996, Barley, S. R. 1986). The same lesson applies to bureaucracy: the impact of procedures or formal positions in cross-expertise collaboration is not exclusively due to their intrinsic features, but the context in which bureaucracy operates also plays a fundamental role. Although a list of all the variables interfering with the role of bureaucracy in PlaneCo would be unattainable, I highlight three conditions which my fieldwork revealed to be most salient: the familiarity of workers with bureaucratic elements, their endorsement of them, and the flexibility they enjoy in their use. I review each one in turn in the following sections.

Familiarity with Bureaucratic Elements

The familiarity of workers with bureaucratic arrangements is central for the positive role of bureaucracy in cross-expertise collaboration. While this may appear borderline commonsensical, studies confirm that individuals rarely have a complete knowledge of the norms, routines, and processes which make up their work environment (Vaughan 1997, Hodson et al. 2013). This is especially true in companies with multiple projects and departments that are slightly independent from each other — such as in PlaneCo — in which it is not uncommon for employees to be unaware of the work processes of colleagues from 'distant' areas of the organization (see the concept of structural secrecy in Vaughan 1997). When workers lack an understanding of procedures, they risk having clashing ideas on how to deal with certain situations.

For example, someone unfamiliar with the ambassador office in PlaneCo would not regard those occupying such position as having the legitimacy to discuss issues on behalf of functional leaders. This would erode the lateral hierarchy structure. By the same token, an expert unacquainted with the knowledge exchange registry might consider it simply as an aide-mémoire, thus disrupting the expectations around the binding value of recorded agreements. A similar point is made by Adler and Borys (1996) on the importance of transparency in an enabling bureaucracy (i.e., the ability of workers to understand the functioning of and rationale behind standardization and procedures)

Certainly, breaches in expectations regarding bureaucratic arrangements cannot be entirely avoided. However, for the most part, workers are reasonably familiar with the bureaucratic arrangements in the engineering unit. Long-term employment is high, which means that most experts have a long tenure in the company and are thus accustomed to its procedures and routines. In addition, the transit of specialists across projects fosters a uniform understanding of organizational processes throughout the workforce. PlaneCo also employ specific strategies to further familiarize workers with bureaucratic arrangements, including training courses about the product development model and company processes. Manuals and guidelines are available on the corporate intranet while dashboards feature core information about projects (e.g., agenda of meetings). Finally, when all fails, individuals are subject to sanctions for not following the formal processes — punishment is an effective (although hard) way to gain familiarity with norms (Emirbayer 2003).

Endorsement for Bureaucracy

Endorsement from employees plays a fundamental role in fostering the benefits of bureaucracy for cross-expertise collaboration. By endorsement I do not mean blind acceptance of bureaucratic processes, but more generically some form of buying-in for it. Overall, in PlaneCo, workers consider the bureaucratic arrangements explored in the previous chapters as appropriate. Therefore, it is a situation similar to the one that Gouldner classifies as representative bureaucracy, one in which there is a shared agreement among management and workers about (the importance of certain) rules (Gouldner 1964).

The organizational literature documents the fact that the lack of endorsement may trigger workarounds, shadow systems, or even open contestations (Berente and Yoo 2012, Blau 1973, Gouldner 1965). In the case of PlaneCo, we might expect workers to boycott formal processes that they do not consider respectful of occupational norms (e.g., workers could boycott the zonal analysis if they did not find it an appropriate method for technical problem-solving) (Tuertscher et al. 2014). Contrary to this, in PlaneCo, experts deem most of the checklists, standards, scripts, and similar apparatuses as 'essential' for the adequate progress of the product development (or at least agree with the intent behind them). Indeed, although the attention towards controlling the participation in meetings might appear to be at first coercive, workers perceived it as quite justifiable given its overall goal of involving expert groups in systemic matters.

Endorsement stems from many sources. Most notably, the first is given by the congruence between the (organizational) goals of bureaucratic mechanisms and the professional values of engineering unit workers. For example, as suggested previously, both place a premium on the technical solutions that 'incorporate' the concerns of the relevant specialists. Employees routinely joked about silos while perceiving the procedures in technical meetings and the coordinator office as mechanisms to achieve the necessary systemic solutions that aircraft development requires.

Endorsement also stems from the involvement of workers in the creation of bureaucratic elements. Many times bureaucratization initiatives are led by the employees themselves. For example, the information collector tool was created by drafters and the product development model emerged through a series of meetings with representatives from core company areas. In a similar vein, bureaucratic processes enjoy support from workers because they build upon existent structures. For example, senior experts are usually the ones who occupy the ambassador office. This makes the office an organizational formalization of an existent occupational hierarchy.

Flexibility When Dealing with Bureaucratized Processes

Flexibility is the third variable influencing the ability of bureaucracy to enable collaboration. In this context, it does not mean arbitrariness — by definition the contrary of bureaucracy — but discretion. PlaneCo employees are able to bend procedures as long as they do not harm organizational goals. This reflects what Adler describes as a bureaucratic arrangement which capitalizes on, instead of substituting, workers' judgment (as in a typical tayloristic arrangement) (see Adler and Borys 1996). In other words, it is one in which bureaucratic apparatuses are tools which enable workers (instead of de-skilling them).

As documented in the literature, adjustments prevent bureaucratic structures from becoming stifling (see the idea of adjustive development in Blau 1973). Without flexibility, PlaneCo workers would be forced to follow protocols (or depart from them at their own risk) even when they are detrimental to the product development. Employees are quite aware of this peril and openly acknowledge the importance of flexibility. For example, the members of some configuration control boards reflected that it was necessary to step outside their responsibilities in order to fulfill their mandate in situations of time pressure/emergencies (e.g., requesting swift checks and approvals).

Flexibility is inbuilt into PlaneCo's formal structure. For one, experts have room for maneuvers when dealing with bureaucratic elements. For example, in the zonal analysis, action items cannot be wished away, but ownership over them can be transferred; the attendance of experts is controlled via signatures, yet groups are free to send replacements. This gives experts some latitude. Flexibility is also present to the extent in which the focus of regulation is more on the goals to be achieved than on the precise means to reach them. For example, presentation templates and checklists are designed to foster the participation of the relevant specialists in technical meetings. Yet, their use is elective. The locus of control is on the involvement of experts in discussions, not on whether workers use the templates.

Of course, no work system is perfect, and neither is bureaucracy in PlaneCo. Nevertheless, these three conditions help counter some of the most usual shortcomings of bureaucracy. This includes the rigidity and stiffness typically imputed to it (Crozier, 2010 [1964], Merton 1940). For example, if experts did not have the discretion to decide when to use formal knowledge exchanges tools (e.g., knowledge sharing), too many resources would be poured into simply administering all the information being circulated among experts. In addition, these conditions also help to distill the much-feared problem of goal displacement (Merton 1940). If workers in PlaneCo were oblivious to the reasons behind product development procedures, and unable to adjust them according to particular situations, they would be more likely to turn them into ends in themselves.

Is This (Still) Bureaucracy?

At this point one might wonder: is it sensible to speak of bureaucracy given the particular characteristics and conditions described above? The answer is yes. Bureaucracy in PlaneCo focuses mostly on lateral relations, in contrast to what is usually expected to be its locus par excellence (i.e., individual tasks). Also, the bureaucratic arrangements described are quite plastic and accommodating of the work practices of technicians and engineers; conversely, bureaucracy is usually associated with compulsory processes. Thus, one would be tempted to employ a new label to refer to the precise bureaucratic structure of PlaneCo (a collaborative bureaucracy?). This, however, would be a misguided idea. As explained in Chapter 2, bureaucracy is present to the extent in which certain arrangements promote the rationalization of work (not whether they match a certain ideal type or not) (Gouldner 1964, Clegg and Lounsbury 2009, Albrow 1970).

With this, I go against the tendency of authors to invent neologisms for particular organizational arrangements linked to bureaucracy (Sturdy et al. 2014, Hodson et al. 2013). As suggested in Chapter 2, this strategy is problematic because it preserves a narrow idea of "bureaucracy" as unrelated to lateral organizational processes. For example, neo-bureaucracy scholars see integration (more specifically, cross-functional teams) as a characteristic of neo-bureaucratic organizations, while (traditional) bureaucracy is associated with specialization (Sturdy et al. 2014). Contrary to that, I argue that bureaucracy hinges on the rationalization of work activities — whether they be vertical, horizontal, individual, distributed, etc. Thus, as shown in this thesis, bureaucracy may be linked to (and enabling for) lateral processes, cross-functional teams, and integration mechanisms.

Theoretical Implications

Implications for Cross-Expertise Collaboration

The vast scholarship on cross-expertise collaboration, reviewed in Chapter 2, mostly overlooks bureaucracy or takes it as the nemesis of collaboration. In different streams of studies, work across expertise domains seems to unfold in a bureaucratic void, without any organizational structures, formal processes, and regulations (Bechky 2003, Carlile 2002, Barley, W. 2015, DiBenigno and Kellogg 2014, Kellogg et al. 2006, Majchrzak et al. 2012, Bruns 2013, Ben-Menahem et al. 2016, Pine and Mazmanian 2017, Nicolini et al. 2012, Heckscher 2007, Scarbrough et al. 2015). Contrary to this, the present thesis shows that bureaucracy is not only very much present but it is also an important factor in these dynamics. At the foundation of some sacred cows of collaboration, such as multidisciplinary meetings or systemic solutions, there are a lot of ordinary procedures, routines, and formal positions. This brings a number of implications for the literature.

First, and most importantly, this thesis turns current thinking on the topic around by showing how bureaucracy can represent an infrastructure for cross-expertise collaboration (Star 1999, Star and Ruhleder 1996). By reducing uncertainty, it enables experts to engage in focused and productive exchanges and interactions (Tsoukas 2009). More specifically, bureaucratic arrangements clarify accountabilities and priorities (Pine and Mazmanian 2017, Dougherty 2008, Okhuysen and Bechky 2009); they highlight "who knows what" and facilitate connections (Gardner 2016); they enforce the integration of a plurality of interests/perspectives (Oborn and Dawson 2010, Liberati et al. 2016, Contu 2014); they foster systemic solutions and well-balanced decisions (Majchrzak et al. 2012, Hansen 2009); they check whether experts' activities progress and are in sync (Dougherty 2008, Sosa and Eppinger 2007, Sosa et al. 2004, Hansen and Nohria 2004); and they diminish collaborative overload (Gardner 2016, Cross et al. 2016, Cross 2013).

Second, and related to the previous point, this thesis contributes to taking bureaucracy out of the shadows of cross-expertise collaboration studies. There is an apparent unwillingness/inability of authors to recognize bureaucracy as what it really is: one just needs to consider the apparent preference for using euphemisms such as 'structure,' 'formalization,' or 'work process system' for bureaucracy (Pine and Mazmanian 2017, Song and Chen 2014, Valentine and Edmondson 2015). Against this backdrop, the present thesis shows the value of bureaucracy in cross-expertise collaboration extensively and puts forward less caricatured conceptualizations of the phenomenon.

Third, the thesis foregrounds the centrality of control in cross-expertise work, a theme which has usually been overlooked in current scholarship. Although many scholars of knowledge work focus on the ideas of control and autonomy (Brivot 2011, Huising 2014, Waring and Currie 2009), scholars often portray collaborative activities as unfettered from organizational hierarchy and governance, especially those associated with a symbolic interactionist perspective (Crozier, 2010 [1964]). Yet, as shown in this thesis, cross-expertise collaboration is not always governed by specialists themselves (Carlile 2002, Carlile and Rebentisch 2003, Bechky 2003, Truelove and Kellogg 2016). Formal regulation mechanisms, including managers, may play an important role in orchestrating exchanges and interactions.

Fourth, the ‘infrastructural’ focus on bureaucracy puts the nose of cross-expertise collaboration students on the ground. The extant literature has a penchant for ‘superstructural’ discussions on the quality of relations among experts (Gittell and Weiss 2004, Gittell 2004); the level of commonality/sharedness among them (DiBenigno and Kellogg 2014, Carlile and Rebentisch 2003, Bechky 2003); and the presence of communitarian goals or shared values guiding their work (Heckscher 2007, Adler et al. 2008). This thesis takes this conversation to a more mundane level. It shows that some well-esteemed collaborative elements, from systemic solutions to participative processes, start with experts getting the information they need from each other within certain timeframes and being co-present in meetings — all of which may benefit from routines which monitor information exchanges and procedures to control attendance at meetings (see also Nicolini, 2012 et al., on the ‘mundane’ infrastructural support for collaboration).

Implications for Expertise Coordination

The literature on expertise coordination is a sub-set of the one on cross-expertise collaboration. Therefore, many of the underlying assumptions are the same, including the skepticism about bureaucracy (Okhuysen and Bechky 2009, Ben-Menahem et al. 2016, Bruns 2013, Majchrzak et al. 2007, Faraj and Sproull 2000). The general idea is that bureaucracy is only positive in situations in which work tasks are repetitive. Conversely, this thesis shows that bureaucracy is also relevant in complex work settings, such as aeronautical product development. This brings two implications to the extant literature on the topic.

First, the thesis disputes the idea that lateral integration mechanisms/emergent coordination practices and bureaucracy are mutually exclusive. As explained in Chapter 2, the common assumption is that bureaucracy plays no part in meetings, teams, and integration roles (Galbraith 1995, 1974, Mintzberg 1980, Mohrman 1993). In contrast to this dichotomy, this thesis shows that these processes may work thanks to, or at least together with, bureaucracy. In PlaneCo, offices in the lateral hierarchy underpin integration roles while cross-disciplinary meetings follow (and benefit from) procedures and routines. Moreover, coordination practices in PlaneCo, such as adjusting work priorities, depend on a particular governance structure (cf. workflow synchronizing in Ben-Menahem et al. 2016, and alignment in Bruns 2013). All this highlights that bureaucracy may co-exist with — and sometimes even be complementary to — integration and coordination processes.

Second, this thesis highlights the enduring importance of formal organization elements in the coordination of expertise in complex environments. Current studies disdain standards, procedures, and similar structural mechanisms (Faraj and Xiao 2006, Bruns 2013). Conversely, this thesis shows that these formally-designed mechanisms are still important in work contexts characterized by intricate interdependencies. With this, I retrieve the early insight that in situations of reciprocal interdependence, coordination by standards and plans remains relevant (see Van de Ven et al. 1976 for the co-existence of different coordination modes). I therefore respond to the call to examine the relevance of formal, as much as informal, elements in the coordination of cross-expertise work (Ben-Menahem et al. 2016, McEvily et al. 2014).

Implications for Bureaucracy

This thesis has five implications for our understanding of bureaucracy, a concept that albeit present in organizational and management scholarship since its inception, suffers from cycles of popularity and neglect, as well as prejudices, stigma, and misunderstandings (Adler and Borys 1996, Adler 1999, Baehr 2001, Courpasson and Reed 2004, Greenwood 2005, Gajduschek 2003, Adler 2012, Merton 1965, Gouldner 1955, Weber 1978).

First, this work reinforces the idea that bureaucracy is not a universal construct. Bureaucracy appears in most of the literature as a black-boxed element that varies in degree (rarely in kind) according to changes in the organizational environment, company size, and task complexity (Walsh and Lee 2015, Perrow 1986). Thus, while scholars explore in what kind of contexts (a higher or lower degree of) bureaucracy is most suitable, or assess its impact in different settings, the assumption is that it is always an immutable pre-determined 'thing' (see Bunderson et al. 2016 for a similar argument on hierarchy). Alternatively, this thesis join forces with those who stress that bureaucracy exists in different configurations that may produce various outcomes according to contextual factors (Adler and Borys 1996, Adler 2006, 2012). In particular, my work suggests several variables to be taken into consideration when examining the impact of bureaucracy in contemporary work (i.e., familiarity, endorsement, and flexibility).

Second, and related to the previous point, this thesis demonstrates the poverty of conceptualizing bureaucracy through pre-determined characteristics (Clegg and Lounsbury 2009). Since bureaucracy exists in infinite configurations, there is no 'final' list of features for it. Nevertheless, most authors analyze bureaucracy according to the adherence of an organization to the classic Weberian ideal type or to simplified versions of it (Bunderson and Boumgarden 2010, Walsh and Lee 2015, Robertson, M. and Swan 2004, Stinchcombe 2009). With this, they overlook the fact that central to the Weberian conceptualization is the process of work rationalization — and not just a list of variables. To be fair, there is much value in attending to the mechanisms and features identified by Weber to understand bureaucracy (and I have done so in this work). However, one needs to refrain from using them just as an analytical sleight of hands: one should ask not only whether certain bureaucracy apparatuses exist (e.g., written records), but how they operate in a given context.

Third, the thesis (empirically) rescues the original meaning of bureaucracy put forward by Weber: uncertainty reduction (Gajduschek 2003, Weber 1978). Throughout the management and organization literature, there is a deep-seated misunderstanding that bureaucracy is engineered for efficiency (see Chapter 2). Yet, in reality, bureaucracy represents a system to reduce uncertainty, making work processes more unambiguous, calculable, reliable, and precise (see Gajduschek 2003). This misconception impedes authors from adequately appreciating the value of bureaucracy, since it leads them to search for its benefits in the wrong place. While this point has already been made by analysts of bureaucracy (Gajduschek 2003), my thesis helps to show in practice how bureaucracy reduces uncertainty in a complex work setting.

Fourth, and also a consequence of the previous three points, the thesis suggests that 'traditional' bureaucratic mechanisms might be present in (new) organizational forms usually defined as alternatives to it. Put simply, the thesis has some implications for discussions on post-bureaucracy, neo-bureaucracy, and non-bureaucracy. Authors associated with these ideas many times conceptualize bureaucracy in a reified manner as a fixed series of traits (e.g., Weberian ideal type) against which they make assessments about 'new' organizational forms (Heckscher 1994, Sturdy et al. 2014, Gittell and Douglass 2012). In the process, however, they mischaracterize bureaucracy and miss the fact that the existence of bureaucracy is not found in the presence or absence of some traits such as specialization/integration, but in whether work processes unfold in a unambiguous and calculable manner or not (cf. Sturdy et al. 2014). In line with that point, the thesis has shows that behind organizational processes typical of modern complex organizations, from knowledge sharing to brainstorming, there might be 'traditional bureaucracy technologies' such as written documentation and workflows.

Fifth, the thesis as a whole highlights the need for a more appreciative and empirically-based study of bureaucracy (Adler and Borys 1996, Gouldner 1955). One that invites scholars to examine in concrete terms how bureaucracy shapes work and organizational processes before making sweeping claims on its positive/negative value (cf. Hamel 2014). Speaking about Taylorism, Littler expressed the following: "to understand the changes in the forms of work organization … it is necessary to penetrate the clichés about Taylorism" (Littler 1978: 199). The same is true in the case of bureaucracy. To debate its nature and consequences in abstracto is senseless. Bureaucracy is a machine which structures work processes (Weber 1978). As such, its outcomes depend on its enactment (an insight shared with studies of technology in organizations) (Adler and Borys 1996, Barley, S. R. 1986). Still, scholars routinely jump the gun to conclusions without fully grasping the situated ways through which bureaucracy functions in particular contexts (for a related argument see Dougherty and Corse 1995). This tendency is present even in studies which are appreciative of bureaucracy, such as those which refer to enabling bureaucracy but gloss over how it specifically generates enabling outcomes (Song and Chen 2014). Thus, to the question of whether bureaucracy is or does something, we need to ask in response: which enactment of bureaucracy (see also Gay 2005).

Practical Implications

This thesis acts also as a reminder of the importance of functional structures and specialization more generally in light of the pro-team bias of the literature on collaboration (Hansen 2009, Gardner 2016, Tett 2015). Scholars assume that (cross-functional) teams and related arrangements are the golden standards to promote integration in organizations — especially in situations where innovation is desired (Brown and Eisenhardt 1995, Edmonson and Nembhard 2009, Holland et al. 2000).

A similar idea is also present in publications on aeronautical product development which sing the praises of design-build teams (i.e., self-managing groups of specialists working on the same aircraft parts) (Ilcewicz et al. 1991, Altfeld 2010). In parallel to this 'romance of teams' (Allen, N. J. and Hecht 2004) there is a devaluation of functional organization and specialist work — functional departments are now understood as silos and abominated (Gulati 2007, Johannessen et al. 1997)

As an alternative to that, the thesis describes the case of a (bureaucratic) product development organization successfully handling complex interdependencies without much reliance on (cross-functional) teams. Integration follows a more structured pattern with specific channels and intermediaries: instead of a design-build wing team, we have a 'wing coordinator' pulling together specialists (see section above on streamlined integration). This configuration preserves the typical advantages of functional arrangements, including economies of scale (Galbraith 1993), clearer and more manageable responsibilities (Child 2014), lower coordination costs (Adler 1995, Tushman and Nadler 1978, Sherman and Keller 2011), and deeper specialization (Galbraith 1971).

I do not claim that the structure of PlaneCo is more or less effective (still for what it is worth, PlaneCo planes are well-respected in the aeronautical sector with a time-to-market that fits, and sometimes outperforms, industry benchmarks). Nevertheless, the case shows that team arrangements are not the only appropriate option for aeronautical product development, and complex knowledge work more generally. Therefore, instead of launching crusades to break down functional departments, connecting them through definite mechanisms might suffice to enable collaboration.

Another ingrained assumption in the discussions about collaboration inside and outside academia is that it only thrives in 'organic' contexts understood as "free flowing systems" which lack procedures and formalization (see Dougherty 2008 for a critique). The recipe for collaboration is usually one prescribing the removal of hierarchy, procedures, and norms while relying on mechanisms such as shared values, common ground, and inter-personal relations to fuel collaborative/participative processes. The idea is that collaboration (especially among highly-skilled workers) flourishes when you leave workers to their own devices, self-organizing their interactions, and informally sorting through controversies (Bruns 2013, Ben-Menahem et al. 2016, Seidel and O'Mahony 2014).

Conversely, this thesis shows that formal structures might be enabling (or even necessary) for collaboration. For example, in PlaneCo formalization drives meetings to be more participative and inclusive of the perspective of various experts; in addition, it also pushes experts beyond narrow perspectives and towards systemic solutions. While the literature offers general and inspirational suggestions on how to nurture collaboration — such as, cultivating a particular profile in leaders (Hansen 2009) — my fieldwork highlights the fact that collaboration might benefit from more 'engineered' strategies. As suggested previously by Craig, controls and procedures may be used to pull experts together towards a consistent direction (see Craig 1995 for an appreciation of bureaucracy).

Boundary Conditions and Future Directions

The emerging insights on the enabling role of bureaucracy in cross-expertise collaboration discussed in this thesis are tied to some specific boundary conditions. In particular, they are more applicable to workplaces characterized by complex projects (e.g., large infrastructure projects) and regulated operations (e.g., nuclear plants). Also, in the specific case of innovation work, I expect that bureaucracy will have the enabling roles documented in thesis incremental innovation work, but not necessarily in radical innovation as these latter contexts might require a more 'abductive' form of work organization (see Dougherty, 2017).

On a more general scale, the enabling capacity of bureaucracy might also be impacted by the absence of long-term employment, organizational commitment, and worker autonomy and voice. This is because workers in settings with a high turn over and/or low commitment are more likely to be less familiar with bureaucratic procedures and the rationale behind them — factors which are central conditions mediating the impact of bureaucracy on collaboration and organizational dynamics. By the same token, in situations in which workers have little autonomy, they might lack the necessary resources to deal with bureaucratic structures in a flexible manner. Finally, when workers have limited voice on the way bureaucratic structures are designed and enacted, they might be less supportive of them (as they will perceive them as external and alienating). These are however all hypothesis and further research is needed to further elucidate whether or not bureaucratization is sufficient to promote a healthy collaboration or whether and to how extent it depends on the underpinning factors listed above.

In addition, regarding opportunities for research, there are also important limitations in my work which future studies could address in order to further refine our understanding of the link between bureaucracy and collaboration. First, I explored cross-expertise collaboration in a context with requisite integration. Thus, the question remains whether bureaucracy has the same enabling impact in settings where integration is not a requirement and activities present a reduced level of interdependence. It might be the case that such a system of checkpoints and procedures for ensuring synchronicity in operations is more adequate (and necessary) only in situations in which the object of work has a complex nature.

Second, I focused on the intermesh of bureaucracy and collaboration while glossing over the (historic) origins of bureaucratization. Therefore, I encourage future studies on the emergence of bureaucracy with a particular focus the creation of formal mechanisms aimed at facilitating collaboration. This may help us to understand whether bureaucratic mechanisms enable collaboration 'by design' or whether this happens in an unplanned manner. Most of the PlaneCo mechanisms discussed here seem to have the implicit goal of facilitating interactions (and not so much of controlling individual work). One may thus wonder: is it just a coincidence? Were previous formalizations unsuccessful? If so, why? What is the agency of workers in generating/molding bureaucratic arrangements to enable collaboration?

Third, I concentrated more on interactions among expert groups than on individual experts while overlooking the individual differences within specialist groups. Thus, individual-level variables such as trust and interpersonal ties did not factor into my analysis. Studies which are more attentive to the individual level could shed light on the extent to which personal characteristics influence bureaucratic arrangements, in particular the way in which specialists perceive and engage with formal mechanisms. Some senior workers in PlaneCo saw formalization in a positive light and as important to nurturing an awareness among junior employees of interdependencies. The outstanding question, however, is whether this is truly the case.

In all this, my call, like the one of social scientists before me, is for not throw bureaucracy away as a concept. Social sciences in general — and organization and management studies in particular — suffer from a novelty bias. New notions are proposed while incoming generations abandon the conceptualization of the classics (Adler 2009). This runs against the importance of cumulative knowledge-building in science. To harness previous insights and concepts is to access a stock of knowledge that might help us to understand the world around us by standing on the shoulders of giants, as the expression suggests. Therefore, to ignore bureaucracy — or worse, to misrepresent it — is a disservice to those who came before us

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APPENDIX

Table 9. Summary Interviews

	Interviewee Position	Interviewee Expertise/Department	Interview Duration
1	Employee	Product Development Excellence	120′
2	Supervisor	Knowledge Management	150′
3	Technical Leader	Product Development Sustainability	76′
4	Supervisor	Research & Development	60′
5	Employee	HR (Engineering Division)	60′
6	Employee	Process Improvement	50′
7	Manager	Corporate Quality	60′
8	Manager	Structural Engineering (Chief Engineer's Office)	67′
9	Manager	Engineering Tools	78′
10	Employee	Corporate Excellence	60′
11	Supervisor	Product Development Excellence	62′
12	Employee	Conceptual Design Engineer	30′
13	Employee	Coordinator (Avionics)	142'
14	Manager	Safety Engineering (Chief Engineer's Office)	75′
15	Manager	Product Drafting	81′
16	Employee	Manufacturing Engineering	73′
17	Manager	Structural Engineering	97′
18	Manager	Maintenance Engineering	53′
19	Manager	Interior Systems Engineering	75′
20	Employee	Configuration Control Board Chairman	81′
21	Employee	Coordinator (Generalist)	70′
22	Manager	Corporate Excellence	90′
23	Employee	Manufacturing Engineering	109′
24	Manager	Program Manager	87′
25	Manager	Aeronautics Engineering	105′
26	Manager	Flight Test Engineering	104′
27	Employee	Drafting & Supplier Management	100′
28	Manager	Electrical Engineering	160′
29	Employee	Professional Educational Programs	50′

30	Employee	Flight Operations Support	104′
31	Supervisor	Supply Chain Management	45′
32	Manager	Maintenance Engineering	77′
33	Employee	Product Engineer (Generalist)	56′
34	Employee	Coordinator (Generalist)	71′
35	Supervisor	Manufacturing Engineering	35
36	Employee	Coordinator (Cost Management)	74′
37	Employee	Coordinator (Manufacturing)	36′
38	Supervisor	Electric Systems Drafting	61′
39	Employee	Coordinator (Core Aircraft Systems)	96′
40	Manager	Chief Product Manager	70′
41	N/A	Junior Liaison from External Supplier	60′
42	Employee	Flight Test Engineering	60′
43	Supervisor	Configuration Management	42′
44	Employee	Structural Drafting	75′
45	Supervisor	Project Planning	42′
46	Employee	Flight Test Engineering	94′
47	Supervisor	Project Planning	34′
48	Employee	Project Planning	30′
49	Employee / Ambassador	Accounting	60′
50	Employee	Project Planning	60′
51	Employee	Project Planning	60′
52	Employee	Configuration Control Board (Manufacturing)	60′
53	Employee	Propulsion Engineering	82′
54	Employee	Flight Test Engineering	108′
55	Employee	Configuration Management	60′
56	Employee / Ambassador	Information Technology	105′
57	Employee	Corporate HR	104′
58	Manager	Product Integrity	130′
59	Manager	Corporate Excellence	93′
60	Supervisor	Corporate Excellence	64′
61	Technical Leader	Aerodynamics (Chief Engineer's Office)	50′

62	N/A	Senior Liaison from External Supplier	60′
63	Employee	Configuration Control Board (Supply Chain)	70′
64	Manager	Chief Product Manager	53′
65	Employee	Configuration Control Board (Supply Chain)	39′
66	Employee	Safety Engineering	137′
67	Employee	Configuration Control Board (Supply Chain)	106′
68	Employee	Flight Controls Systems Engineering	83′
69	Manager	Aerodynamics (Chief Engineer's Office)	83′
70	Manager	Program Manager	60′
71	Employee	Configuration Control Board (Manufacturing)	47′
72	Employee	Safety Engineering (Chief Engineer's Office)	75′
73	Employee	Product Development Excellence	60′
74	Employee	Technical Norms (Chief Engineer's Office)	77′
75	Supervisor	Structural Engineering	55′
76	Employee	Configuration Control Board Chairman	68′
77	Employee	Structural Drafting	62′
78	Manager	Chief Product Manager	77′
79	Manager	Research & Development	90′
80	Employee	Coordinator (Horizontal Stabilizer Section)	66′
81	Technical Leader / Ambassador	Air Management Systems Drafting	95′
82	Employee	Engineering Tools	93′
83	Employee	Customer Excellence	100′
84	Employee / Ambassador	Flight Test Engineering	80′
85	Employee	Portfolio Management	46′
86	Technical Leader	Structural Engineering (Composites)	60′
87	Employee	Weight Engineering	180′
88	Employee / Ambassador	Air Management System Engineering	53′
89	Employee	Safety Engineering	80′
90	Employee	Product Drafting (Generalist)	96′
91	Employee	Coordinator (Planning)	51′
92	Employee	Market Intelligence	50′
93	Employee	Coordinator (Wing Section)	60′

94	Technical Leader	Product Drafting (Generalist)	60′
95	Employee	Product Drafting (Generalist)	73′
96	Manager	Production Planning	83′

Table 10. Summary Shadowing

	Position of Shadowed Professional	Expertise and Attributions of Shadowed Professional
1	Ambassador	Product Excellence
2	Coordinator	Structural Engineering / Wing & Pylon Section
3	Coordinator	Horizontal Stabilizer Section
4	Coordinator	Aerodynamics
5	Coordinator	Core Aircraft Systems and Certification
6	Coordinator	Landing Gear / Wheels, Tires and Breaks / Flight Control Systems
7	Coordinator	Interior Systems
8	Chief Product Manager	N/A
9	Ambassador	Air Management System Drafting
10	Coordinator	Wing Section