Ergonomics, safety, and resilience in the helicopter offshore transportation system of Campos Basin

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Abstract.
BACKGROUND: Air transportation of personnel to offshore oil platforms is one of the major hazards of this kind of endeavor. Pilot performance is a key factor in the safety of the transportation system.

OBJECTIVE: This study seeks to identify the ergonomic factors present in pilots’ activities that may in some way compromise or enhance their performance, the constraints and affordances which they are subject to; and where possible to link these to their associated risk factors

METHODS: Methodology adopted in this project studies work in its context. It is a merging of Activity Analysis (Guerin et al. 2001) of European tradition with Cognitive Task Analysis (CTA – www.ctaresource.com) articulated with the recent approaches to cognitive systems engineering developed by Professors David Woods and Erik Hollnagel. Fifty-five hours of field interviews provided the input for analysis.

RESULTS: Sixteen ergonomic constraints were identified, some cognitive, some physical, all considered relevant by the research subjects and expert advisers

CONCLUSIONS: Although the safety record of the personnel transportation system studied is considered acceptable, there is low hanging fruit to be picked which can help improve the system’s safety.

Keywords: Cognitive ergonomics, cognitive task analysis, safety, helicopter operation

1. Introduction

The notion that accidents and incidents are caused by human errors or mechanical failures is widespread. It still guides much of what is done in the safety domain, but we must recognize that in complex systems, conditions may emerge where certain outcomes come to be beyond the reach of operators’ actions [1]. Coming to grips with the idea that accidents can be primed by complex socio-technical systems designed or operating inadequately relative to the capabilities of their human operators, especially in regard to aspects of their cognition, is an important first step in building resilient and safe systems [2,3].

This study seeks to identify instances where, in their eyes, helicopter pilots’ work taxes them unduly or unnecessarily, working from the premise that ergonomic aspects of critical work can have an impact on the safety of that work. This research uses a cognitive engineering [4] framework to study the operational conditions in which pilots carry out their work and to assess them ergonomically.

About 80% of the oil extracted in Brazil comes from this Basin, located a 3 hour drive north of Rio de Janeiro city, and approximately 400 pilots and co-
pilots working for 9 helicopter companies transport about 40,000 people who work on ships and platforms every month, in 6,300 helicopter flights. These large numbers provide the motivation for the research project of which the ergonomic component of pilots' activities is reported here. The main goal of the project is to analyze and discover how the transportation system is resilient and brittle given the workload demands and economic pressures. The ergonomic analysis uncovered factors that impose demands upon the pilots' and some of their strategies for coping with them.

Flying helicopters in the personnel transportation service for the offshore oil and gas exploration and production operations in the Campos Basin is a demanding activity associated with one of the major hazards of this kind of endeavor. In the Campos Basin, the offshore platforms are located about 100 km from the coast, and this transport has resulted in several accidents. These accidents were related to helideck operations and helicopter failure during flight.

This research uses ergonomic methods to examine constraints associated with pilot's work in the helicopter transportation system for the Campos Basin oil fields in Brazil. The study team carried out and analyzed 55 hours of interviews with aviators (pilots, co-pilots, and managers) of some of the main helicopter companies. The initial objective of the research program was to map the constraints to which air-crew are subjected in the course of their daily activities. Constraints are factors that in some way hamper what is done or how things are done, and are the object of various coping strategies. As a general rule these factors can contribute to undesirable system occurrences, generating micro incidents [5], but they are insufficient, in isolation, to provoke incidents or accidents [6]. Nonetheless, the aggregate load and/or wear and tear generated by the accumulation of many small constraints under the faster, better, cheaper organizational environment can impact system performance and safety [7], and be the cause of great losses. One of the fronts for progress on safety therefore depends on providing conditions which mitigate these constraints, including identifying the safety/production tradeoffs made by people during their daily work [8].

2. Methods

Cognitive Task Analysis (CTA) based on field studies is the natural methodological framework for this study. CTA is a ubiquitous description for a number of methods used to elicit knowledge from professionals in specific domains. According to Crandall et al. [9] CTA is a set of methods to study and describe reasoning and knowledge in context. These studies include the operators' activities of perceiving and attending that underlie performance of tasks, the cognitive skills and strategies needed to deal with complex situations, as well as the purposes, goals, and motivations for cognitive work [9].

Among these methods, we adopted the Ergonomic Work Analysis (EWA), an approach used by the French ergonomics school (e.g. De Keyser and Nyssen [10]), based on activity theory (Engenstron [11]), in which the subjects are observed/interviewed in their actual work setting.

This qualitative ethnographic framework implies that the researcher collect empirical data while interacting with people under study. The observation/interviewing in situ implies the daily taking of field notes (supported by electronic media – audio and video recording) that record naturally occurring talks and interactions between observed actors. Particularly, we want to stress that this method of field observation is especially suitable for study of work organization issues, enabling access to the backstage activities where workers hold the tacit competencies that make possible all the cooperative strategies essential to the accomplishment of daily work. This strategy of gathering data allows grasping the vivid social scenes with accompanying conflicts, misunderstandings, processes of negotiation among actors, creations of consensual arrangements to disrespect prescriptive rules ... that often come together with jargons, gestures, jokes, and so forth.

Finally, ethnographic research assumes that there is no independence between the collection of empirical and all the interactions that occur between the field observer and the insiders. This is to say that all these interactions, occurring between the researcher and people under study, have to be considered as empirical data that will be classified as part of the theoretical analysis.

2.1. Research setting: Campos Basin oil and gas exploration

The sedimentary area known as Campos Basin covers an area of around 60,000 square miles on the northern coast of Rio de Janeiro state. On shore, the boundaries of the basin are outlined by the hills surrounding it. More than a thousand oil and gas wells, 38 fixed and mobile production platforms, over 2,500 miles of
submarine pipelines, production of more than a million barrels of oil and 15.7 million cubic meters of gas per day, which is around 80% and 42% of the national production, respectively, operate in dozens of oil fields. With most of the fields 100 kilometers or more from shore, the production platforms have been designed as self-contained units with their own power supplies and accommodation for staff and the helicopter transportation system has become the only option available, mainly due to the lower transportation time when comparing to the older catamaran transportation system.

To explore different kinds of oil and gas fields and for different types of exploration and production activities there are many different platform types, requiring different helicopter landing approaches. The main types of platform used are fixed platforms, jack-up platforms, semi-submersible platforms, drill ships, and Floating production, storage and offloading vessels (FPSO) platforms.

2.2. Sample characterization

The sample we studied was defined by combination of opportunity and intent: opportunity since we could only interview volunteer pilots who were on duty but not flying, a routine and fairly common situation which arises from aircraft unavailability; intent as from the available pilots we could have made choices seeking to maintain a balance of company roles among the participants in our study. It turned out that the pilot mix and numbers available closely matched our planned sample profile and size, and all comers were interviewed.

Although for the full study other categories were interviewed, only the aviator category and its sub-categories are reported on here due to our focus on ergonomics in this paper. The category descriptions are presented below:

Aviators: Everyone licensed to fly helicopters, including pilots, co-pilots, and operating company managers whose job descriptions required them to hold a valid pilot’s license (pilots + co-pilots);
Pilots: Everyone licensed to command a helicopter and cleared to do so by their companies, and who occupy helicopter operating company pilot or aviator management positions;
Pilots/non-management: Pilots charged only with flying and commanding helicopters, with no management or statutory responsibilities beyond their aircraft;
Pilots/management: Pilots with management or statutory responsibilities within a helicopter operating company (equipment chief, flight coordinator, etc.);
Co-pilots: Licensed helicopter pilots assigned to the co-pilot role by the companies due factors such as not having met the company’s time with the company requirement, the contractor’s time in the basin requirement, or lack of available pilot positions in the company. It is not unusual for a co-pilot to be more experienced and/or qualified than fellow pilots.

Breakdowns of the category sizes in the research setting and in the research sample, and allocated research efforts are presented below.

The interview times presented reflect the research effort dedicated to each role. That there is difference between interview times to interviewee times is due to the fact that some sessions interviewed more than one participant simultaneously. This difference is adjusted for in the interviewee count considered when calculating the mean interview durations. The data reflect the fact that the co-pilots were more forthcoming and eager to participate and as a rule made more time available than the pilots, and that among the pilots, the ones holding management positions did likewise relative to those only flying.

2.3. Data collection

2.3.1. Getting situated: Regulatory structure of the activity

To prepare for their data collection interviews with operators, presented in more detail below, the research group familiarized itself with their activity’s regulatory structure, through interviews with two Commanders, both flight safety consultants. In addition to other information, the flight safety consultants listed the official bodies with regulatory authority over the activity, the set of rules, regulations, and laws that govern the activity, and briefly presented the contractual relationships between the service users and the helicopter operating companies, and between these and the aviators. The network of governing bodies, companies, rules, and regulations that establish the framework in which pilot’s activities are carried out was mapped out by the research team and the resultant diagram validated by the consultants.

2.3.2. Field work: Helicopter operators report on their activity

Once the relevant parts (for purposes of this study) of the Regulations had been studied, the group set out
to establish contact with aviators engaged in the Campos Basin passenger transportation helicopter flying activity using cognitive task analysis techniques [9].

Field data collection was mainly conducted through extensive interviews with operators (active pilots and co-pilots) that were recorded, and the recordings were later transcribed. Due to the aircrafts' restricted cabin space and cargo capacity, and to the lack of contractor's consent, the team had no opportunity to make direct in-flight observations of airmen's activities. In addition to aviators, other participants in the air transport system that interact with them were interviewed at the same or lesser depth. All participants were volunteers.

During the interviews, the interviewers took notes of the issues raised by the interviewees, and immediately afterwards took the time to discuss the content of the interview among themselves, and to write their hot-reports. In the exceptional cases where respondents preferred that their interviews, or parts thereof, not be recorded, more detailed notes than usual were made.

The starting point was the search for detailed understanding of pilots' activities and routine work. To do so, semi-structured interviews were conducted with pilots, co-pilots, and other helicopter operator company personnel over two three month periods a year apart. With few exceptions, meetings were held at the Macae Airport in Macae, RJ. The interviews were conducted in an informal and relaxed tone, intended leave pilots at ease and to promote frank disclosure. With participants' permission, the conversations were recorded and later transcribed for a better use of the information. Several short intervals were left unrecorded by request.

Recurring issues became apparent within the first interviews. To validate these and other issues that were mentioned, we used other interviews, followed up with further reading, and also conferred with domain experts.

As the study progressed several things changed. The structure of the interviews evolved over the period of field studies. In every interview there was an initial period to break the ice, for questions and answers about the research, its motivation, methods, goals, and patrons, and to discuss topics such as confidentiality of the interviews and traceability of sources. In the early interviews, the initial period was followed by a period of free interaction, to a large degree conducted by the interviewees for an audience of attentive listeners (us analysts). In the later interviews, the initial period was followed by a period of structured open questions raised by the interviewers and another dedicated to the review (validation) of interim findings through joint discussion of draft activity diagrams and the list of constraints presented by the research team. Even during the more structured parts of the interviews, researchers remained alert and ready to allow the necessary opportunities for new topics to emerge. After discussing the activity diagrams and constraints list, there was an informal and unstructured short break for rapport, saying thank yous, and goodbyes.

The interviews were conducted many to many, many to one, one to many and one to one, as dictated by circumstances and/or by interviewee wishes. We noted interesting differences in the dynamics of the different types of interview and questioned their impact on the methodological validity of the elicited data. We concluded that these differences within the study sample and in the context of a more qualitative than quantita-
tive study, were not relevant in the scope of this project, and did not compromise the data.

We believe these differences could in and of themselves be an interesting element of study. It remains to be determined whether the memory and verbalization stimuli provided by the more 'conversation' than 'interview' format and the counterpoint of withdrawal and competition due to the presence of others have a net positive or negative effect.

Rather than focusing on how work should be done (the prescribed rules and tasks), we aim to understand how the work is being done and why it is being done in that particular way. This approach recognizes the variability of the workers' activities and that their options—what, when and how to do some action—are afforded and constrained by the work environment. To reconcile the affordances and constraints of the work environment with their own capabilities and limitations, workers can generate a large variety of work patterns including novel behaviors and innovations in work practices, which must be monitored to identify production/safety implications. Although there are different types of constraints rooted at various levels within the organization and the overall system that can shape workers' behavior, allowing for several dimensions of analysis, the results reported here focus on the constraints and conditions of pilots' work activities in the context of their companies' sociotechnical conditions as determined by their investments, maintenance, etc., and their management of human resources, including salary and work rules, as determined by their social policies, work organization procedures, training, etc.

To accommodate characteristics of the pilots' work activities, interview methods were used, avoiding the logistical complications that direct observation of pilots' work activities would entail. The subjects (helicopter pilots and co-pilots and people in different organizational roles) were systematically interviewed. Interviews were recorded with their consent and transcribed to facilitate data analysis. The entire research was done with the support of expert consultants in offshore aviation operations. The final results were validated with pilots, companies, and with the service contractor (the oil company) staff.

3. Results

The data collected in the field lend themselves to different types of analysis and objectives, and we expect that uses will be found for them beyond the scope of this work. In a previous article [10] our focus was the pilots' sacrifice decisions to take off or not when confronted with flaws in the equipment. In this article we describe the main constraints which pilots flying helicopters transporting passengers offshore in the Campos Basin are subject to, mentioned most frequently by respondents.

3.1. A map of the constraints to pilots' activities

Throughout the pilot interview process there were a number of recurring issues. These issues began to emerge as being vital to proper system operation and we identified them as indicators of where to focus our analysis. These are constraints (see Fig. 1), factors that tax operators' performance and can contribute to undesirable occurrences within the system. In general, an isolated constraint is not capable of causing an incident, nor an accident, but the accumulated demands placed on operators by many constantly present constraints may cause large losses.

Identification of the constraints to pilots' activities is in itself an important step toward correcting and eliminating the recurring risk they represent, but safety officers and other professionals involved in the system must take note of these constraints and act so that in due course solutions can be developed to mitigate or extinguish them.

3.2. Roll of constraints, exceptions, accommodations, and differences between activities as prescribed and as practiced

Below we present a list of constraints obtained from the transcription and analysis of the interviews, about which there is broad agreement among the personnel involved, and, when possible, illustrated by representative quotes from the interviews.

3.2.1. Physical environment

3.2.1.1. Local weather and atmospheric conditions

“(…) when it is raining or very windy (…), we must go to an alternative airport. We must contact the [air traffic] control all the time to know about the weather conditions, then calculate the amount of fuel necessary…this is stressful and increases our workload (…)”

“(…) sometimes the wind is coming from the opposite direction when landing, pushing you off the platform, that is tough…(…)”)
Adverse weather conditions that hamper maneuvers, especially landing, are a factor that causes crews great stress. The region where the platforms are located is susceptible to high winds. Dense fog is often present, causing great loss of visibility. These weather conditions are not easy to predict. Pilots gather weather reports before starting their flights, and communicate with radio operators and the three air traffic controllers stationed aboard rigs offshore, but these procedures are not sufficient to avoid unpleasant surprises such as coming across a region of dense fog while operating on information that visibility there is adequate. The lack of visibility may be such as to leave the pilot uncomfortable with the safety of his situation and cause him to abort the flight. When this happens, the pilot may be subject to even greater discomfort from appearing to be malingering.

Another serious concern is the formation of pockets of hot air near the landing sites. This is due to the presence of exhaust vents near the helipads. If an aircraft comes across one of these regions of instability and reduced support during its landing approach, it drops...
abruptly, forcing the pilot to deploy “over torque”, a condition where the turbines are overloaded and which may lead to an accident.

3.2.1.2. Bird collision risk

“(…) Seagulls are the biggest problem, because they’re really stupid and will fly right at you, and won’t keep away. Buzzards see a helicopter and quickly get away, but seagulls don’t. They come for it, and if there’s a collision it can be a serious problem (…)”

“(…) Yesterday a pilot died in Angra and it seems it was a bird that hit the pilot and wound up causing the accident…”

A bird strike is an important incident causing factor (see Fig. 2). Despite the growing efforts of governmental and non-governmental organizations, the number of reported collisions has increased over the years. Improper land-use near airfields, for activities such as open garbage dumps, slaughterhouses, and fish landing sites, attracts ever larger numbers of birds to their vicinity, which increases the risk of incidents.

Statistics indicate that over 80% of bird strikes occur during takeoff, approach, or landing maneuvers, which confirms that the presence of birds near airfields constitutes a real threat to pilots and passengers.

There is a standard set by the National Environment Advisory Board for Airport Safety Areas, regions around the airfields where activities that attract birds are banned. These regions have 20 km radii in the case of IFR (Instrument Flight Rules) capable airfields and 13 km radii for airfields restricted to VFR (Visual Flight Rules).

Since it does not provide for any sanctions or punishment for noncompliance, the Airport Safety Areas standard is often flouted, endangering the lives of airmen. The regulatory process of this very important standard is under way, but, for the time being, activities that attract birds continue to go on in the intended Airport Safety Areas. Bird density near airfields should be considered a safety indicator, since it and flight risk are closely related.

The sanitation problems in the city of Macaé, where several sites are used for open garbage dumps, create an attractive environment that promotes the presence of undesirable birds such as vultures and gulls. The massive presence of birds around the airport is a major risk factor for air activity in the area.

Collisions with these birds are frequent and their outcome can range from a good fright to irreparable helicopter damage or a forced landing. A bird collision with a helicopter windshield may break it and injure pilots and passengers. Birds can also be sucked into a turbine and damage it enough to force single-engine flight or a brusque maneuver with possible disastrous consequences.

Pilots report that because of the birds they are required to pay double attention and that over time they start to recognize the behavior differences between some species of birds.

3.2.2. Operating environment

3.2.2.1. Distance from hangar and offices to the helicopter

When there are no available spots in front of the company’s hangar, the aircraft park at the far end of the airport, about a half mile away. The crew has to walk up to 8 minutes.

“(…) It is almost one km from here to there, an almost 10 minute walk. When there is no space in front you park on the other side and you only have half an hour between flights. From there to here you’ve blown ten minutes. You get here and still need to attend to post-flight maintenance, check the fuel and other items, and go back there to open [the aircraft] for passengers, which takes 7–8 minutes, and all of it in the sun (…)”

“(…) But sometimes he (the pilot) sits there and tells us (the co-pilot) to walk over here, like a camel…”

Pilots and passengers have no way to get around on the apron other than on foot. There are some small tractors and carts, but they are for the exclusive use of maintenance crews and transporting baggage. Macaé airport is about one kilometer long, and none of the apron is sheltered from the sun. Due to the large number of aircraft in operation it is necessary that the whole apron area be used to park aircraft. It is not uncommon for a crew whose hanger is at one end of the field to be assigned to park their aircraft at the other end. Or be it, dressed as pilots, in uniform trousers and shirts, they walk up to about 15 minutes under the Rio de Janeiro summer sun [between flights].

There is no doubt this situation puts a lot of wear on the pilots. Wear that seems unnecessary, given the numerous alternative means of transport that could be deployed to spare them, a point they are keenly aware of. This constraint is closely related to the “short interval between flights” constraint, and addressing it would address that one as well.
3.2.2.2. High temperatures inside the cockpit

“(...) And what other factors That make you tired?”

“Besides the stress there is also temperature, what with that sun out there. Nowadays even in agriculture tractors have air-conditioning, because if not workers don’t produce well. It’s much more tiring ...

“Don’t the aircraft have air conditioning?”

“No, our air conditioning is to fly a little higher. Not even the newer aircraft [have airconditioning]. It’s so as to keep the weight down. Besides being a device that can malfunction, and ground the aircraft. It will increase weight maybe about 30 kilos, but I think the main issue is maintenance as it can be one more source of problems (…)

The aircraft are not air conditioned. Equipment cost has negligible impact on the initial cost of the aircraft, but its weight reduces the load carrying capacity of the helicopter and it generates undesirable maintenance. Pilots and co-pilots constantly mention the wear on them from working in high temperatures. Delays due to the intense air traffic at the airport force pilots to wait long periods for permission to start taxi and takeoff procedures, and temperatures regularly exceed 40°C inside the cabin while the aircraft is parked on the apron at Macae airport. In extreme cases the wait can reach 45 minutes.

3.2.2.3. Excessive vibration in the cockpit

“(...) The beginning of a breakdown is almost always vibration. If the Captain keeps flying with above normal vibration, he will do harm to the whole helicopter and breakdowns will happen one after another. Even the organs of the human body are affected, because each of them works on a frequency. And then one arrives [home] at night and goes to bed more weary than normal, and doesn’t know why (…)

This constraint is more prevalent in older aircraft. In the case of Macaé, the older aircraft that generate pilots’ complaints are the Bell 212 and Bell 412 models. The quality of the flight is directly affected by their vibration. Passengers feel queasy, and the crew experiences above normal fatigue. Pilots also mention the possibility that vibration can cause problems in other equipment, jeopardizing flight safety. Many pilots advocate the retirement and replacement of the Bell aircraft by the more modern S-76A and S-76C + aircraft.

3.2.3. Economic environment

3.2.3.1. Budget constraints in maintenance operations

Conflicts among pilots, mechanics and inspectors were reported. If the Captain writes in the Aircraft Log Book that there is a problem in the aircraft, it is then necessary to ground it (Revenue/contract issues?) and perform the maintenance. Otherwise, the company
may be fined by the regulator. So sometimes pilots don’t write equipment problems or malfunctions in the Aircraft Log, and report it informally – directly to a mechanic – (inconsistent) to keep flying under MEL (Minimum Equipment List) rules. This goes on until the pilot cannot stand it anymore and decides to report it officially. Besides Safety, there is also a conflict with mechanics.

“(…) Sometimes we have to stop an aircraft to get some larger repair service done and the guys (mechanics) keep trying to patch over the problem. (…) they waste time and don’t solve the problem. Until we say, OK, enough, now this really has to happen. We hammer a long time on something everyone knows about: pilots know, mechanics know, the administration knows that it’s no use [patching] anymore, it has to be replaced.”

“(…) But there are equipment failures that cause an aircraft no not comply with the MEL (Minimum Equipment List) requirements, and the aircraft should be made unavailable, grounded. That’s why pilots sometimes don’t record equipment malfunctions immediately in the logbook. But there are breakdowns that maintenance doesn’t repair due to the lack of replacement parts. So they go into patching mode and do something about the problem, but half an hour later, it goes bad again. About then pilot and co-pilot get stressed because the flights become dangerous. There comes a moment when the pilot gets fed up because they aren’t doing anything and records the issue in the aircraft’s logbook, making the aircraft unavailable. There’s an aircraft out there, XXX (prefix deleted), which has recurring problems, where it sometimes gives off a violent burning smell, returns to base, and mechanics find nothing (…)”

Like any business, air taxi companies (the helicopter operators) are always on the lookout for opportunities to reduce maintenance costs. The cost of maintaining helicopters of the size used in offshore passenger transportation operations is huge. Besides the high price of the parts themselves, there are also the expenses of maintaining a crew of highly qualified maintenance and specialized professionals, among others. Additionally there are extended maintenance downtimes due to parts unavailability on the domestic market. During its
downtime an aircraft generates no revenue and if it exceeds contractual allowances on unavailability it will incur stiff penalties. It is worth noting that Petrobras’ contracts for its passenger offshore air transportation services bind specific aircraft, which therefore cannot be interchanged even for another identical one.

Sometimes companies’ withholding of maintenance department funds seems exaggerated. There are situations where due to a company instruction certain routine procedures cease to be performed. An extreme example was provided during one of the interviews: a pilot or co-pilot notices a little play on the joystick and communicates it to the aircraft mechanic upon returning to the hangar; on his next flight he notices the play again and repeats the process, only to find out sometime later that there is a company instruction stipulating that such errors should be ignored until the required replacement parts are on hand so as to avoid the aircraft being grounded while the parts are procured.

This drives a double constraint: the aircraft will operate below optimum for longer than ideal, and pilots and mechanics will be at loggerheads because of the necessarily unclear communication where mechanics seem to accept a task but are in reality unauthorized to comply.

If the situation becomes extreme the pilot may wield his power to impose action by reporting the issue in the aircraft’s log as mentioned earlier. Every aircraft has a logbook that is registered to it at the DAC (Civil Aviation Department) and which is verified regularly. Besides the routine entries made in the logbook, a pilot or co-pilot can describe a failure detected during his last flight. From that moment on the aircraft becomes unavailable for flight until the defect is corrected. Pilots are well aware of the downside of resorting to a logbook entry to tip maintenance’s hand: conflict with maintenance and possibly dissatisfied management.

The situations described above make clear that it is necessary to establish viable limits to control spend-
ing on maintenance. One cannot lose sight of the idea that, in the case of offshore air transportation, this line is thin, and if poorly managed can lead to irreparable damage.

3.2.3.2. **Budget constraints in flight operations (pilot income issues)**

“(…) There are pilots who neglect flight safety to be able to fly more (…)”

“(…) There are cases – with older machines – where the pilot knows he should stop the aircraft due to excessive vibration, but doesn’t and leaves the maintenance period for the other crew so as to earn more. This is bad because although he gets to fly a lot some fortnights, other fortnights another crew may do the same to him and he will spend the time waiting for the aircraft to be repaired (…)”

The companies studied adopt varying pay policies where some [significant] portion of pilots’ and co-pilots’ pay is variable and determined by hours flown. Under these policies each professional receives a salary composed of a fixed portion whose value varies according to job function, seniority etc., plus an amount linked to hours flown during the fortnight. The actual hourly rates vary between companies and between pilots and co-pilots. Considering pilots’ hourly wages to be about twice those of co-pilots, and the variable portion of co-pilots’ pay to account for up to 40% of their total compensation excluding benefits are useful approximations. This can be seen in the table below. This policy aims motivate pilots and co-pilots to fly as much as possible during the fortnight they are in Macaé.

In theory the effort of pilots and co-pilots to maximize their billable hours would not be harmful to the system as the system itself would work to define and restrict the number of hours possible. However, part of the system’s feedback loops on the state of its equipment depends on pilots and co-pilots providing this information. This creates a conflict, as pilots and co-pilots are encouraged to fly as much as possible while being given the task of deciding when to make an aircraft unavailable due to maintenance, and thereby take a pay hit.

The following hypothetical situation was provided by a co-pilot. A pilot and a copilot make the first flight of the fortnight and realize there is a flaw in some sensor. Considering flight safety, the ideal measure to be taken would be to inform the maintenance department and hand the aircraft over to them for maintenance. However, this intervention may take the entire fortnight, leaving the pilot and co-pilot with very few

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**Table 1: Pitch, Roll and Heave use obligatory Petrobras**

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<th>Equipment</th>
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<td>Pitch Roll</td>
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<td>Heave</td>
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| Freqüências de NDB das unidades marítimas.

**Fig. 6. Sample (back) of the Campos Basin map most pilots there use, prepared and sold by a fellow pilot (source: pilots).**
billable hours and consequently less pay in the given month. Another option is to continue flying without reporting the troubled sensor, hoping it won’t be needed, and then report it to maintenance near the end of the fortnight, leaving the next fortnight’s crew to deal with the aircraft’s unavailability.

The decision to notify maintenance could lead to the loss of up to 40% of the month’s pay, depending on the company in question and pilot pay-scale. The fraction of co-pilots’ compensation that varies due to actual hours flown can be as high as 30%.

3.2.4. Socio-emotional environment
3.2.4.1. Pilot/co-pilot relationship

Airmen see themselves as belonging to different classes, among which there are relationship problems. There is rivalry between the civilian and military aviators, and, among the latter, rivalry between the aviators from different forces. These rivalries can become problems when they collide with the rank distinction between pilots and co-pilots (captain and crew, respectively) in the Campos Basin helicopter offshore passenger transportation service companies, where local experience and service time count more than overall experience or service time. Besides the class rivalries, there are personality issues between some of the aviators. Some co-pilots report having relationship problems with certain captains. Many of the captains are aloof, unwilling to teach, and resentful of criticism and suggestions. There were reports of cases where there was no dialogue between pilot and co-pilot other than that required by flight procedures for the full fortnight of their tour together.

Intra-crew hostility is highly detrimental to safe flying, and there is at least one company working on this
issue. As yet, the focus of their work is still toward understanding the phenomenon, rather than implementing any practical measures. Although our access to their work on cabin hostility was restricted, it was clear from interviewing the psychologist responsible for the work that the company considers this area to have great potential to improve flight safety.

Many of the people interviewed are aware of the CRM work going on at different levels and its importance, but are also frustrated with the persistence of problems.

### 3.2.5.2. Rapid changes in flight planning

Most of the pilots reported being surprised by scheduling plan changes during flight operation. These changes can lead to increased stress and pressure on the crew, as they must quickly adapt to new schedules. The interval between successive flights of the same crew is only 30 minutes. During this time, the crew must complete and file a post-flight report and perform a series of tasks to prepare for the next flight such as checking the weather forecast, preparation of a flight plan, and refueling instructions. If we take into account the time needed for the crew to walk from the aircraft's parking position to their company's offices, it's possible to find there is not enough time for a quick break or a simple coffee. Even going to the bathroom can end up being done in a rush.

If we consider a day during which pilots have several flights, the only rest interval is lunch time. This does not seem to be the ideal situation for an activity in which it's necessary to deal with constant stress and pressure.
changes are communicated by radio and have serious consequences on pilot’s workload. Pilots’ mental representation must be changed in order to deal with these new tasks’ cascades.

“(…) You get out of here with everything ready, all right. I go to such a place, caught many passengers, etc. Then on the way the radio reports a change in schedule. I usually walk away with everything just right, with flying around the head. I have to take off here, warning here, this radial. Changes when I get lost. Okay, now where do I go? What do I do? Changes all in your head. For me it greatly increases the stress (…)”

3.2.5.3. Lack of standardized identification of the production units

According to Brazilian Navy procedures the oil rig identification must be written in the helipad decks instead to be on the rig sides that facilitates an identification anticipation process. This change according to pilots will improve the operation safety in the region.

“(…) On this issue the landing, a big problem I see now is that there is proper identification. There is no standardization, it is sometimes very difficult to identify the ship or the correct platform (…)”

“(…) Have identification on the deck, but it had to be more visible and easier to identify. This is a big
problem in small ships. In each ship stays in one place and that this identification leads to greater difficulty, you have to pay more attention (…)"

3.2.5.4. Ship operations

In the case of small ships, the natural difficulty of landing on platforms is redoubled. The helipads tend to be very high, making it so that even a light swell results in large amplitude displacements of the landing site. Another problem is the natural position of the vessel in accordance with the ocean currents, which does not always mean the best position for helicopter approaches that depend on the wind. Sometimes, pilots are required to request that the vessel be repositioned. As this is a time consuming maneuver, it is not always possible for the aircraft, flying with limited fuel reserves, to await its conclusion.

Many pilots suggested gathering the passengers to or from these small vessels on larger platforms nearby, and use sea transportation for the final leg.

3.2.5.5. Limited contingency fleet

In the Campos Basin there’s no back up aircraft to rescue passengers at sea. There is consensus among the
pilots of the importance of such an aircraft. In addition to the demand voiced by the air-crews for the existence of a rescue craft, the same demand has been voiced by the Union of Workers in the North Fluminense Oil Industry (RJ-Sindipetro).

The rescue helicopter should be able to take-off and land on water, carry equipment suitable for rescuing people at sea, and have a crew of professionals trained for this purpose, and should be on standby during all hours of offshore flight operations.

To bolster their case for a rescue helicopter, pilots recounted an incident where after a forced landing in the sea, all passengers left the craft safely and were in lifeboats awaiting rescue. Helicopters flying in the vicinity could do nothing more than observe the downed passengers in the lifeboats and report their exact position to air traffic control. By the time the rescue boat got the passengers ashore, 5 h 40 min had elapsed from the time of the crash landing.

3.2.6. Flight infrastructure
3.2.6.1. Congested radio communications
All the people interviewed complained about the radio system. Many of them have stories of incidents that happened because of miscommunications.

Near the oil rigs there are aircrafts trying to communicate with the platform’s radio. At these moments when communication is crucial it becomes com-
Fig. 12. Areas of the Flight Planning Report used during a flight (source: authors). (Colours are visible in the online version of the article; http://dx.doi.org/10.3233/WOR-152021)

3.2.6.2. Flight area map is inadequate

One of the issues cited by the vast majority of the respondents was the inadequacy of the Campos Basin regional maps provided by the operators. These maps don’t use color, which makes it difficult to locate some important points, increasing pilots’ cognitive load. Moreover, the size of some information items is too small to be suitably legible for most pilots, a problem that is compounded in the case of some pilots who have hyperopia and/or presbyopia.

As an alternative to the company provided maps, many of the pilots who fly in the Campos Basin buy maps prepared by a fellow captain who also flies there. He updates them every fifteen days using mapping software donated by a consulting company that conducted a study during the 90’s in the region, and sells them for an almost symbolic price. This map, besides using color, presents its data in a more appropriate scale, including a larger scale detail box covering the part of the field more densely occupied by the various rigs and ships, significantly reducing pilots’ cognitive loads.

3.2.6.3. Flight plan form is inadequate

Although flight planning is formally attributed to the captain, in practice this activity is shared with company officers and the co-pilot. The captain nonetheless retains ultimate responsibility for all aspects of flight planning.
The data that determine the flight plan are the flight’s legs (intermediate destinations) and loads (passenger and/or cargo weight), elements defined by the client company, as well as the aircraft’s characteristics, and meteorological conditions. From these, flight times, fuel consumption, and extra fuel requirements are calculated. All flights require an extra fuel provision to allow for unexpected events, and the size of this provision varies according to the rules governing the flight, whether visual or instrument flight rules (VFR or IFR), which in turn depend on weather conditions.

To support the feasibility of the turnaround time between flights, and make the pilots’ task easier in general, companies perform part of the flight planning work. One of the helicopter operating companies to which we had access provides crews with computer generated flight plans with their flight data filled in as well as pre-calculated time and fuel consumption estimates and passenger boarding/deboarding tallies in reports titled “Visual Flight Planning Report” or “Instrument Flight Planning Report”, depending on the weather conditions.
Airmen recognize benefits in the computer-generated Flight Planning Reports we analyzed, but are quick to point out several shortcomings, and to demonstrate various strategies to get around those and meet their needs. It is possible that the report is being used for purposes beyond those of its initial design and this may explain the deficiencies pointed out by aviators, but regardless of the origin of the condition, it is clear that this artifact is inadequate for its current use. We have not had access to the development team that produced the artifact and we have no information about the scope of the original flight planning report project.

Several helicopter operating companies have not participated in this study yet, and there may be better practices and artifacts in use in some of them, but there is a consensus among the pilots interviewed that the company procedure shown here as an example is the most advanced.

Briefly, the prescribed process consists of the carrier passing the initial flight specification information to the crew, who then obtain any necessary additional data and generate operational data to put together a flight plan (sometimes two) to file with the AIS (Airport Information Service) and to use during flight op-

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### Key

- Fuel Calculation
- Flight Operation
- Administrative Information

### Fig. 14. Uses of the data available on the Flight Planning Report (source: authors). (Colours are visible in the online version of the article; http://dx.doi.org/10.3233/AVOR-152021)
<table>
<thead>
<tr>
<th>Etapa</th>
<th>PAX</th>
<th>Embq / Desem</th>
<th>Org / Dest</th>
<th>Peso / NM</th>
<th>VHF / Tempo</th>
<th>Coreção</th>
<th>Total</th>
<th>Combustível</th>
<th>Remanescente</th>
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<td>10</td>
<td>SBME</td>
<td>104°</td>
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<td>00:07</td>
<td>00:49</td>
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<td></td>
<td>PVM1</td>
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<td></td>
<td></td>
<td>1,519 lbs</td>
<td></td>
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<tr>
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<td>00:02</td>
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</tr>
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<td></td>
<td>PVM2</td>
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<td></td>
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<td>00</td>
<td>06</td>
<td>PVM2</td>
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<td>00:08</td>
<td>00:09</td>
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<td></td>
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<td>PVM3</td>
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<td></td>
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<td>00</td>
<td>04</td>
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<td></td>
<td></td>
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<td></td>
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</tbody>
</table>

**Tempo total de vôo:** 02:27 + 00:30 = 02:57

Fig. 15. Example of a possible Flight Plan form lay-out within an A5 page format compatible with the cockpit clipboard, with two lines per flight leg and space for writing down flight timing events (source: authors).

In the case of the sample report presented here, in addition to the flight specification information provided, there is a recommendation of flight rules to adopt in light of the current weather conditions and an initial fuel requirement estimate. The information layout is more appropriate for an administrative than an operational report, and the existence of a notice warning that the report and its planning are experimental and should not be used as an official flight plan was pointed out by the respondents. Pilots question the maintenance of this warning and the reports’ experimental status for over a year, and point out that the captain is responsible for all aspects of a flight, regardless of whether there is a written warning or not. They also complain of the report’s poor use of the available space. They are quick to point out that the block of lines that provide detailed passenger loading and unloading information at each stop, which they refer to as up-and-down, seems to have been an afterthought. The amount of data that may be present in this report, which may reflect flights with up to 16 legs, and which merges data needed at different stages of the flight planning and execution process, imposes the use of small text and A4 paper.

**Tempo total de vôo:** 02:27 + 00:30 = 02:57

Fig. 16. Usage example of the possible two lines per leg Flight Plan form showing pilot’s records of events (source: authors).
The use of small font sizes is a problem as it makes reading the text difficult for pilots with presbyopia, an as yet unquantified but nonetheless significant group. The A4 paper size is a problem because it is twice the size of the clipboard available in the cockpit and therefore makes it so that parts of the report are not readily accessible in flight. As the report layout does not group the information needed in flight in a small enough area, simply folding the report does not solve the problem. While some pilots resort to transcribing information from one area to another on the sheet so as to enable a single fold, others prefer to use multiple folds to make the report fit the small format (a complex procedure they jokingly refer to as origami), and others are content to keep flipping the sheet over during the flight. A single pilot may adopt any one of the various strate-
gies to fit the report to inflight constraints depending on the number of legs and/or flight time. This lay-out issue becomes ever more critical as the number of legs on a flight increases. This is so because the data, activity and the complexity of the activity increase with the number of legs, while the time to deal with them decreases, making the lack of space even more present.

In the following pages we present the Flight Planning report (Fig. 8) and show how pilots prepare it to better suit the requirements of inflight use. Figure 9 illustrates the process they call ‘origami’, and Fig. 10 the process of transcription. As noted earlier, there are pilots who use the report as is or just folded in half (not represented here). We have also highlighted in the illustrations the information necessary calculate fuel requirements, to carry out flight operations, and for administrative use. Lastly we present these three demands simultaneously, which clarifies the apparent advantage of adding all elements in a sheet.

Due to the constraints to which pilots are subjected during flight, especially lack of space, lack of time, and moments of intense activity, the report’s disadvantages, namely its physical size, the use of small fonts, poor information distribution, and the presence of information not used in flight, exceed, by far, any advantage to serve various purposes with a single report.

It is interesting to note that although the limited space available in flight evidently is a constraint, it does not figure among the constraints identified through the interviews. This is due to the fact that it is accepted by the pilots as a premise, which they label as a restriction, but they do not mention it in the sense of something that bothers them.

Separating the functional components of the Flight Planning report into two or three separate reports, one for flight operation, and the other(s) for flight planning and administrative needs, can result in reports better suited to their use by reducing the total volume of information in each report and thereby allowing that information to be better laid-out according to the dynamics of its use.

With this in mind, we developed two alternative preliminary layout proposals for a Flight Plan geared for use while operating the flight. Both layouts have an A5 form factor. The biggest difference between the two layouts is the allocation of one (Figs 17 and 18) or two (Figs 15 and 16) lines per leg of the flight. The proposed layouts allowed the use of larger fonts and left space for taking notes on about flight events. The two lines per leg alternative more so than the other. For each layout, an example of how this could be used to take notes in flight has been included, with the notes represented in blue Staccatto font.

4. Conclusions

We describe how the ergonomics methodologies can be used to uncover constraints of a complex system, the Campos Basin helicopter transportation system, and provide useful insights about system safety and resilience. Although the safety record of the personnel transportation system studied is considered acceptable, our research showed that there is low hanging fruit to be picked which can help improve the system’s safety. The constraints uncovered reveal that the system performance and behaviors did not facilitate the development of buffer capacities throughout the system that facilitate people’s work and decisions. Our analysis does not aim the produce a complete set of recommendations to improve the system, as the official accident reports try to do. Our aim was to shed some light about how the Campos Basin helicopter transportation system is actually functioning, because for a system to be controllable, it is necessary to know what goes on inside it and the ergonomic methodology provide a sufficient clear description of the system. We do believe that without a clear description of the system constraints, if we do not known what really happens inside it, then it is clear impossible to control it effectively, as well as to provide meaningful recommendations about specific points or systems functions to improve the safety. To implement specific recommendations about the need to review and/or to follow rules and procedures, to provide more training, supervision and so forth, as indicated by accident investigations, without understanding the real nature of system operation, will not produce the desired outcomes, because underlying behaviors will be soon drifted again to produce new unwanted outcomes.

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