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D-7 REPORT ON SOLUTIONS IN RELATION TO BREAKS DUE TO PHYSIOLOGICAL NEEDS

eMCO-SiPO – Extended Minimum Crew Operations-Single Pilot Operations

An Agency of the European Union

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SUMMARY

In the current regulation (CAT.OP.MPA.210) it is stated that “during all other phases of flight each flight crew member required to be on duty in the flight crew compartment shall remain at the assigned station, unless absence is necessary for the performance of duties in connection with the operation or for physiological needs, provided at least one suitably qualified pilot remains at the controls of the aircraft at all times”. Since these conditions can no longer be met during eMCO and/or SiPO operations, in this task the suggestions proposed by the industry regarding the opportunities to take physiological breaks were studied.

First, a literature review was executed regarding the proposed solutions. Available medical-physiological data on frequency and urge of human physiological needs was analysed and the experience with solutions in other domains was collected.
Important considerations with respect to the suggested solutions were:

1) Can pilots always prevent an urge to use the toilet over a period of 2-3 hours?
2) How much time does it commonly take to empty one’s bladder or bowel and/or for menstrual care?
3) Are there medical conditions affecting frequency and/or duration of toilet use?

Based on the available literature it is anticipated that the majority of healthy pilots can prevent the urge to urinate over a period of 2-3 hours by using the toilet before the start of that period. However, in case of significant caffeine intake, drinking larger volumes of fluids, and some medical conditions, an acute urge to void may necessitate toilet use before the end of this 2-3 hours period. In addition, several studies found that a strong urge to void may lead to cognitive impairments, such as a change in performance, and a deterioration in reaction time and working memory. It is also anticipated that a majority of healthy pilots can prevent an urge to defecate over a period of 2-3 hours by using the toilet before the start of that period. However, it is known that uncontrollable bowel action and “other” gastrointestinal symptoms can occur, and will necessitate the PF (and/or PR) toilet use within this period of 2-3 hours. Finally, it is expected that there will be cases of unexpected menstruation problems that will necessitate toilet use by female pilots within a period of 2-3 hours.

Several solutions for aircrew bladder and bowel relief were found: diapers, disposable urine collectors, bladder relief systems, and diet solutions. It was concluded that while these measures may possibly be enforced in military aircrew in order to successfully achieve a military mission, they are considered unacceptable for civil airline pilots, due to adverse medical and human factor (distraction, unhygienic, discomfort) effects, ethical considerations, and a lack of acceptance by the pilot community.

Next, an online survey was distributed among CAT pilots to assess the (dis)advantages and practical implications of the possible solutions. Additional interviews with a small group of pilots were held as well. Based on the outcomes it was shown that the average time in between toilet breaks of healthy pilots is a little more than 2 hours, but that large individual differences (e.g. based on age) exist. The results also showed that it is possible to some extent to schedule and/or postpone toilet breaks (e.g. by means of altered drinking patterns), but that the possible bowel and/or bladder relief solutions are considered unacceptable.

An additional search of relevant accident databases showed that in civil aviation one incident has been attributed to physiological needs. However, because of the fact that any sort of impairment resulting from physiological needs cannot be determined post-mortem, it should be acknowledged that more accidents might have taken place.

By means of the findings above, and the review of these by a multidisciplinary team of experts within the consortium, it was concluded that the proposed eMCO segment duration of about 2.5 hours could cover the time between toilet breaks for a large part of the pilot population, but will also result in relative frequent cases of the PF needing to go to the toilet before the end of the eMCO segment concerned. It should therefore be anticipated that there will be occasions that the PF urgently has to use the toilet during the time period that s/he is scheduled to fly the aircraft during cruise flight. Since withholding urination or defecation may lead to a deterioration in aspects of cognitive function, the PF should go to the toilet whenever needed during the EMCO segment. In that case (s)he would need to request the PR to take over, thereby disturbing the PR's sleep. Furthermore, as most probably the physiological urge will be high, it might not be possible for the PF to wait for the sleep inertia of the PR to be over, this would lead to a condition where the PF would need to be considered as incapacitated while the relief pilot might still be affected by some degree of sleep inertia. Either way, it would end the EMCO segment. In conclusion, due to human physiological needs, in an eMCO operation with only one pilot at the controls, it is inevitable that occasionally the eMCO segment must be terminated prematurely to address these needs.

CONTENTS

ABBREVIATIONS

ACRONYM	DESCRIPTION
AAIB	Air Accidents Investigations Branch
AMXDmax	Aircrew Mission Extender Device
ATPL	Airline Transport Pilot Licence
BPH	Benign Prostatic Hyperplasia
BSFS	Bristol Stool Form Scale
CAT	Commercial Air Transport
CONOPs	Concept of Operations
CR	Controlled Rest
DLR	German Aerospace Centre
EASA	European Union Aviation Safety Agency
eMCO	Extended Minimum Crew Operations
EVA	extra-vehicular activity
FDP	Flight Duty Period
GA	General Aviation
IUD	Intra-Uterine Device
LDA	Latent Dirichlet Allocation
MAG	Maximum Absorbency Garment
NASA	National Aeronautics and Space Administration
NLR	Royal Netherlands Aerospace Centre
OAB	Overactive Bladder
OEM	Original Equipment Manufacturer
PF	Pilot Flying
PM	Pilot Monitoring
PR	Pilot Resting
PVT	Psychomotor Vigilance Task
RCO	Reduced Crew Operations
SIPO	Single Pilot Operation
ToD	Top of Descent

1. Context

1.1 Background

Due to the ongoing developments in technology, automation and autonomous unmanned aircraft, combined with the outlook of worldwide pilot shortage, there is an interest and desire to explore whether it is feasible to operate commercial air transport (CAT) with reduced flight crews in large aeroplanes. This feasibility needs to be considered from both the safety as well as efficiency perspectives.

Current legislation, as stated in both Air Operations Regulations as well as Certification Standards, require a minimum crew of two pilots:

- ORO.FC.200 states that aeroplane operations under instrument flight rules (IFR) or at night with a turbo-propeller aircraft with a minimum seating capacity of more than nine, or a turbojet aircraft, requires a minimum flight crew of two pilots.
- CS25.1523 states that the minimum flight crew must be established so that it is sufficient for safe operation. Although the Certification Standards therefore do not explicitly state that two pilots are required, all current aircraft regularly used in CAT are certificated for operation with a minimum crew of two pilots.

EASA was approached by aircraft manufacturers regarding the regulatory and safety aspects of such new concept of operations (CONOPs). Two specific CONOPs were identified:

- Extended Minimum-Crew Operations (eMCOs) are defined as operations with one pilot at the controls for extended periods during the cruise flight phase, while the other pilot(s) are resting; however, offering at least an equivalent overall level of safety through compensation means (e.g. ground assistance, advanced cockpit design with workload alleviation means, pilot incapacitation detection, etc.). It is, in particular, relevant to large aeroplanes operated in CAT operations, for which no fewer than two flight crew members are currently required as per the Air Operations Regulations. The concept of eMCO is also commonly referred to as Reduced Crew Operations (RCO). In this report where relevant the terminology “eMCO” will be used, but this must be regarded as interchangeable with the term “RCO”.

- Single-Pilot Operations (SiPOs) are defined as end-to-end single-pilot operations. Annex III (PART-ORO) ‘Organisation requirements for air operations’ to the Air Operations Regulation already foresees conditions and limitations under which these types of operations are allowed. In the future, it is expected that these conditions and limitations will need to evolve in order to extend single-pilot operations to large aeroplanes, provided that compensation means (e.g. ground assistance, advanced cockpit design with workload alleviation means, capability to cope with pilot incapacitation, etc.) are in place in order to provide for at least an overall level of safety equivalent to today’s two-pilot operations.

1.2 Scope of the document

In the current regulation (CAT.OP.MPA.210) it is stated that “*during all other phases of flight each flight crew member required to be on duty in the flight crew compartment shall remain at the assigned station, unless absence is necessary for the performance of duties in connection with the operation or for physiological needs, provided at least one suitably qualified pilot remains at the controls of the aircraft at all times*”. Given the CONOPs as described above, these conditions can no longer be met. The current Task 7 report therefore provides an overview of the suggested solutions proposed by the industry concerning breaks due to

physiological needs for the pilot-flying during the single-pilot phase of flight, and a discussion of the possible solutions, including their applicability during the different types of operations, and their impact in terms of safety and associated mitigation measures.

1.3 Objective

In this task the suggestions proposed by the industry regarding the opportunities to take physiological breaks during eMCO and/or SiPO operations were studied, and their effects on safe flight monitoring were considered. If applicable, a distinction was made between eMCO and SiPO solutions. Factors that were included in the analyses were the effects and opportunities of strategic scheduling of in-flight rest and the opportunities to mitigate discomfort in case of extreme physiological urgency.

2. Approach

1. First, the currently proposed solutions by the industry (OEMs and airlines) were reviewed and categorised. These findings could be used as input for the literature search, so that no solutions or mitigations from the industry were be missed, nor that any additional information about these solutions was required beforehand.

2. Next, a literature review was executed regarding the proposed solutions on allowing breaks or not. Available medical-physiological data on frequency and urge of human physiological needs (urination, defecation, bowel habits) was analysed. In addition, experience with innovative solutions in other domains (such as general aviation, military aviation, or space) was collected as well.

3. Furthermore, an electronic survey was distributed among CAT pilots. By means of the survey, a group of pilots was asked how they currently schedule their toilet breaks. As a result of this operational perspective, the (dis)advantages and practical implications of the possible solutions from both literature and industry were assessed. Additional interviews with 3 to 4 CAT pilots were held to gather their perspective, and multiple databases were searched for aircraft accidents and incidents related to physiological needs.

4. Finally, the content of the current report was reviewed by a multidisciplinary team of experts within the consortium, including a safety expert, human factors specialist, pilot representative, and a medical doctor. These experts weighed the feasibility and impact of the proposed solutions as well.

Based on the approach above, this report provides an overview of the suggested solutions offered, including their applicability during the different types of operations, and their impact in terms of safety and associated mitigation measures.

3. Results

3.1 Review of solutions by the industry

During normal operations with two crew members in the cockpit it is allowed that one of the pilots temporarily leaves the controls in case of duties in connection with the operation or for physiological needs. During all other phases of flight, each flight crew member required to be on duty in the flight crew compartment shall remain at the assigned station, provided at least one suitably qualified pilot remains at the controls of the aircraft at all times.

While during an eMCO segment, the cruise flight phase is ensured by a Pilot Flying (PF) alone, there is a need to provide an optional possibility to manage the physiological needs of the PF. At the time of the start of this specific task targeting solutions in relation to breaks due to physiological needs (December 2023), information from two OEMs was available. The information shared made clear that these OEMs have quite similar ideas regarding the management of physiological needs.

The information the first OEM (OEM1) provided regarding the topic was rather limited. Based on several discussions it could be derived however that OEM1 foresees that during an EMCO segment, the Pilot Resting (PR) is resting in a bunk outside the cockpit, while the PF is alone in the cockpit for about 2 hours. The location of the restroom would be located inside the cockpit, however there would be no view of the instruments nor would there be any possibility for interaction with ATC. As such, when the PF needs to attend to physiological needs in this concept, temporarily there will be no qualified pilot at the controls of the aircraft.

The second OEM (OEM2) provided more extensive information through their CONOPs documents. OEM2 stated that “the envisaged operating method shall be compatible with human being needs, notably thirst, hunger and physiological breaks”, and that in their point of view, the pilot alone at the controls shall never leave the control station. Accordingly they indicate that:

- The pilots need to anticipate their physiological breaks when switching responsibilities.
- Any means to meet such a need (water bottle, food, etc.) at the control station may be used as part of the Operator policy.
- The maximum on-board rest time of the PR during an eMCO segment is not expected to last more than 2h30min. This duration aims at avoiding long periods without the possibility of physiological breaks. However, OEM2 also indicates that this duration could be subject to change in later iterations of the concept.
- In case the PF cannot wait for the end of the rest period, (s)he (or an automatic warning signal) should wake the PR to take over. Next, the PF should wait for the duration of the sleep inertia period of the PR to be over, before going to the restroom. If this is not possible, the PF is considered as incapacitated[1].

[1] Please refer to the deliverable of Task 5 for more information on pilot incapacitation.

3.2 Literature review / theoretical support

3.2.1 Sanitary needs problem

What the description of the solutions provided by the OEMs in the previous section makes clear is that if the pilot flying (PF) during an eMCO segment needs to use the restroom, stretch his/her legs, or has other reasons to temporarily leave his/her seat, (s)he has to request the resting pilot (PR) to take her/his place at the controls, and wait for sleep inertia to dissipate before giving in to the physiological needs. As a result, sleep duration and sleep quality of the PR could be affected. Although at this stage only current (2-person) FTL limits are considered, in a future iteration where eMCO rest periods contribute to the maximum FDP this will possibly impact the planned EMCO work-rest scheme and would-be flight time constraints would then have to be re-considered, and possibly cause an in-flight diversion.

Important considerations with respect to the suggested solutions are:

4) Can pilots always prevent an urge to use the toilet over a period of 2-3 hours (e.g. by using the toilet before the start of that period)?
5) How much time does it commonly take to empty one's bladder or bowel?
6) How much time is commonly needed for menstrual care?
7) Are there medical conditions affecting frequency and/or duration of toilet use?

This chapter aims to answer the questions raised, as well as describe the cognitive aspects of a strong urge to void or defaecate, and the potential mitigation measures. In order to do so, a literature review was performed on the available medical-physiological data on the frequency and urge of human physiological needs (urination, defecation, bowel habits, menstruation) and the experience with innovative solutions in other domains (such as general aviation, military aviation, or space).

3.2.2 Medical aspects of urination

The average capacity of a bladder of adult and healthy persons is between 400 and 700 ml of urine. Normal patterns of urination may vary considerably; adults generally void 5 to 6 times daily and the average 24-hour urinary output is 1200 to 1500 ml. Increased urinary frequency may occur because of either increased urine volume or a decreased bladder capacity (i.e., less than 200 ml) (Wrenn et al., 1990). Urine volume can increase by drinking large volumes of fluids, using caffeine, diuretic medication, and diseases such as diabetes mellitus and kidney insufficiency, or having arrhythmias causing a high heart rate. The most common causes of a reduced bladder capacity include infection, involuntary bladder muscles contractions, and low compliance (the ratio between the volume of the bladder and the pressure of bladder muscles).

How long it takes for a healthy human being to empty the bladder has only been studied empirically. Animal studies revealed that for almost every mammal, from elephants to rabbits, it takes on average 21 seconds to empty the bladder. This is considered to apply to healthy humans as well. For operational considerations it is reasonable to estimate that for a normal urination of a healthy pilot a complete visit (going, voiding, cleaning, returning) to the toilet to urinate will take between **5 to 10 minutes**. A typical duration of 5 minutes for a physiological break in current operations was also mentioned in the documentation provided by OEM2.

3.2.2.1 Medical conditions

There are several medical conditions that could affect the frequency and/or duration of urination:

- Benign Prostatic Hyperplasia (BPH) can start in males >40 years and increases with increasing age. It is the most common prostate problem for men older than 50 years of age (Lim, 2017). Symptoms may include frequent urination, inability to delay urination, trouble starting to urinate, weak stream, and

inability to urinate despite feeling an urge. BPH may increase the frequency as well as the duration of in-flight toilet use in pilots, predominately for those over 50 years of age.

- Overactive bladder (OAB) affects approximately 16% of males and females. More than 40% of people with an overactive bladder have incontinence (Reynolds et al., 2016). The main symptom is a frequent feeling of needing to urinate. Urge incontinence occurs when one has a strong, sudden need to urinate that is difficult to delay. The bladder then squeezes, or spasms, and one may lose urine. OAB will lead to an increase in the frequency as well as the duration of in-flight toilet use in both males and females.
- Painful urination (dysuria) in women is often caused by urinary tract infections. In men, it is frequently caused by both urinary tract infections and prostate problems. The symptoms can start acute and unexpectedly. So it can start during a flight, and may cause more frequent toilet use of longer duration, but the pain involved could also lead to incapacitation.
- Diseases such as diabetes mellitus and/or renal insufficiency can also increase the frequency and volume of urination, although most Class 1 (ATPL) pilots will be considered unfit to fly when these diseases are manifested by these symptoms.

Based on the available literature it is anticipated that the majority of healthy pilots can prevent the urge to urinate over a period of 2-3 hours by using the toilet before the start of that period. However, in case of significant caffeine intake, drinking larger volumes of fluids, and the medical conditions as mentioned above, an acute urge to void may necessitate toilet use before the end of this 2-3 hours period.

3.2.2.2 Urge to void and cognitive impairment

It is conceivable that the PF may inhibit voiding despite an urge to urinate because s/he does not want to disturb and shorten the sleep of the PR. Withholding urination however, may -apart from distracting abdominal pain- lead to an increasing sensation of the urge to void and a subsequent transient deterioration in aspects of cognitive function.

Several studies found that a strong urge to void may lead to cognitive impairments, such as a change in performance, with a tendency to hurry (Jousse et al. 2013), deterioration in reaction time and working memory (Lewis et al., 2011), and impairment of sustained attention (during 3 hours of voluntary urinary retention; Griswold et al. 2023).

3.2.3 Medical aspects of defecation

In healthy adults, the average normal *stool frequency* varies between 3 times per week to 3 times per day. The majority of individuals (95.9%) report a bowel movement frequency of 3–21 per week, upholding this metric of normal stool frequency (Mitsuhashi et al., 2017). The most common bowel habit described is once daily; a regular 24 hour cycle was apparent in 40% of men and 33% of women. Another 7% of men and 4% of women seem to have a regular twice or thrice daily bowel habit. As a result, most people showed to have irregular bowel patterns (>50%) (Heaton et al., 1992).

Different criteria for normal *stool consistency*, assessed using the Bristol Stool Form Scale (BSFS), were found for men and women. The BSFS is an ordinal scale of stool types ranging from the hardest (type 1 abnormal hard) to the softest (type 7, liquid stool) (Shokouhi et al., 2022). Among men, 90% reported a BSFS of 3 to 5, but for women (90%) it was 2 to 6. Demographic factors associated with self-reported stool type included male sex, higher education, income, and fibre intake (Mitsuhashi et al., 2017).

How long it takes to empty one's bowel has never been scientifically studied. The time needed normally depends on the stool type and rectal reflex mechanism. Although some stool types (hard, diarrhoea) could take

longer to be completely evacuated, it seems reasonable to allow healthy pilots **10-15 minutes** for a complete visit to the toilet for defecation.

It is anticipated that a majority of healthy pilots can prevent an urge to defecate over a period of 2-3 hours by using the toilet before the start of that period. However, it is known that uncontrollable bowel action (21%) and "other" gastrointestinal symptoms (54%) are involved in 75% of the causes of in-flight incapacitation in airline pilots (Green and James, 1991). Therefore, the occurrence of these symptoms in the PF (and/or PR) will necessitate toilet use within this period of 2-3 hours.

Syncope during Micturition or defecation syncope
It should be considered that in case of using the toilet because of gastro-intestinal problems (diarrhea, nausea, vomiting, abdominal pain) the PF should declare that s/he is incapacitated and should request the PR to take over immediately. This is recommended because there have been several reported cases of aircrew not returning from the toilet or collapsing (syncope) on their way to or from the toilet (BEA, 2011; ATSB, 2016). More information on accidents and incidents can be found in section 3.5.

3.2.4 Menstruation

During a menstruation period women may need to go to the toilet for care. It is anticipated that a majority of healthy female pilots can anticipate to bridge a period of 2-3 hours without needing to use the bathroom for menstrual care. However, it is known that unexpected *intermenstrual bleeding* may occur, needing a unanticipated bathroom visit. The prevalence of intermenstrual bleeding is highest in the perimenopausal years. Among naturally menstruating British women aged 40-54 years, the 2–year cumulative incidence of intermenstrual bleeding proved to be 24% (Shapley et al., 2013).

Another unexpected need to use the bathroom may be a *breakthrough bleeding* which is a common concern among 20% of women using hormonal birth control, such as birth control pills or hormonal IUDs (intra-uterine devices) (FSRH, 2020). Oral anticonception is also used by women who want to delay or prevent their menstrual period in relation to work or sports events. Furthermore*, unexpected withdrawal bleeding* may be caused by discontinuing or switching methods of hormonal birth control (Schrager, 2002).

Based on the above-mentioned facts, it is expected that there will be cases of unexpected uterine bleeding or unexpected heavy bleeding during menstruation that will necessitate toilet use by female pilots within a period of 2-3 hours. The time needed for menstrual care depends on the problem that is causing the discomfort. In most cases **10 to 20 minutes** seems to be a reasonable estimation.

3.3 Methods for aircrew bladder and bowel relief

Information on solutions used in other domains (such as general aviation, military aviation, and space) was collected in order to identify possibilities for bladder and/or bowel relief in case of urgency and/or when it is unsafe and/or impossible for the PF to leave the controls. The following solutions were identified.

3.3.1 Diapers

Several types of adult diapers have been developed, for instance the Maximum Absorbency Garment (MAG), for NASA astronauts. The MAG is an adult-sized diaper with extra absorption material that the astronauts wear during liftoff, landing, and extra-vehicular activity (EVA) to absorb both urine and feces. The MAG can hold a maximum of 2 liters of urine, blood, and/or feces, and an astronaut can go 8 to 10 hours without needing a change. The adverse effect of diaper usage for urine and feces collection is inflammation of the skin in the diaper area (called diaper dermatitis). Urine can also increase the permeability of diapered skin to irritants and can directly irritate skin when exposure is prolonged (Berg et al., 1986). Apart from these common adverse effects,

sitting for several hours in wet and smelly diapers can be (very) uncomfortable and may lead to distraction of flying tasks. Moreover, effective diapers consist of several layers of absorption material and such thick diaper does not comfortable fit in the trouser of a regular airline uniform. Because of the above, diaper usage will most probably not be accepted by the representative pilot unions. As a result, it can be concluded that due to the adverse medical and human factor effects, the use of diapers is not feasible as a solution for eMCO flights.

3.3.2 Disposable urine collectors

Military fighter pilots can urinate in a disposable urine collector (called Piddle Pack – see Figure 3-1~~Figure 3-1~~ on the left, available for both males and females). Besides that this is considered unhygienic and uncomfortable, urinating in a Piddle Pack will at least need the assistance of one hand and will therefore distract the pilot concerned. Due to the flight suit, defecation in a urine collector is even more difficult and distracting (as a result, in fighter pilots defecation will often be done using a diaper). In addition, nine deaths have been reported that were linked to crashes involving sanitary problems in USAF F-16 fighter jets and A-10 attack planes (Task and Purpose, 2021).

In general aviation, so called TravelJohns (Figure 3-1~~Figure 3-1~~ on the right) or plain (plastic) bottles are sometimes used by males for urgent urination. Disadvantages of using these types of urine collectors are similar to those of the Piddle P acks: one is distracted in such a way that it can be considered as a temporary impairment. Both the bottles and TravelJohns are suitable for male pilots only.

It can be concluded that it is highly undesirable and not recommendable for male and female airline pilots to use a urine collector for a PF during an eMCO segment as a solution for physiological needs, due to the distraction and temporary impairment, as well as due to the unhygienic conditions and discomfort that the collectors may cause.

Figure 3-1. Piddle Packs (left) and TravelJohn (right)

3.3.3 In-flight Bladder Relief System

Another commercially available solution for military pilots is an in-flight bladder relief system called Aircrew Mission Extender Device (AMXDmax[2] - see Figure 3-2~~Figure 3-2~~**Error! Reference source not found.**). This device was developed for the US Air Force to replace the use of urine bags, and to prevent aircrew from deliberate dehydration. The system is hands-free, battery operated, and can be worn underneath especially designed flight suits. The device can be used by both males and females: it collects urine in a cup for males, and in a pad for females. Embedded with sensors, the device detects urine and pumps it into a collection bag through an external connection. The AMXDmax is only capable to handle urine (defecation still has to be done in a diaper).

This device is considered not suitable for airline pilots because it does not allow to change one's body position to reach all controls in a normal-sized cockpit of an airliner. In addition, it is not suitable for bowel relief, it is not possible to wear this device using a normal airline uniform.

Figure 3-2. Male and female version of the AMXDmax.

3.3.4 High protein, low residue diet

One solution was found that did not concern the excretion, but the intake of nutrients. While operating at a very high altitude for a long period of time (e.g. 8-12 hours), pilots of U-2 reconnaissance aircraft have been equipped with flight suits that came with a special contraption to handle urine. However, similar to the solutions described above, defecating would only have been possible in a diaper, which was considered unacceptable because it would have unacceptably distracted the single flying pilot and the pilot would have to fly for several hours in a smelly and unhygienic diaper. For that reason, the aircrew had to also use a high-protein, low-residue diet for at least 24 hours prior to a mission. The rationale was to provide food which could be almost completely absorbed from the gastrointestinal tract, thereby leaving a minimum of residue for the formation of feces and intestinal gases (Phillis and Sears, 1995).

While, these measures may possibly be enforced in military aircrew in order to successfully achieve a military mission, they are considered unacceptable for civil airline pilots. Regular and frequent use of such diet will at least lead to medical adverse effects on intestinal physiology. Moreover, it is arguable whether it is ethically justifiable to make it necessary for a pilot to use such measures. This holds for specific diets, but also for wearing diapers.

[2] https://apps.dtic.mil/sti/tr/pdf/ADA601354.pdf

3.4 Survey and interviews

3.4.1 Survey methods

To serve the objectives of both task 5 and 7, an on-line survey was distributed across different European pilot organisations, including airlines and pilot unions. The survey included 31 questions concerning the informed consent, demographics and practical questions. Specific topics addressed were (subtle) incapacitation, sleep inertia, fatigue, physiological needs, and a category "other", which allowed the respondent to leave any additional comments on eMCO SiPO. The questionnaire and all its items can be found in report D-5.

The survey was opened on 20 November 2023 and closed on 18 December 2023, allowing 6645 full responses (4646 incomplete responses were excluded). Further data processing steps involved filtering out the unrealistic values, nonsense responses, or responses that did not meet the criteria set in the question. For this report, only the answers to the physiological needs questions and the "other" category were considered.
The three questions asked in the physiological needs section were:

- What is your approximate interval between toilet breaks during a flight?
- Do you schedule your toilet breaks in a certain way (y/n)?
- What do you do in order to schedule your toilet breaks?

The "other" question was the following:

- In case you have any other considerations regarding eMCO SiPO, (subtle) incapacitation, sleep inertia, fatigue or physiological needs during flight that you would like to say, please type them below.

3.4.2 Survey results

Based on 6092 responses to this specific question on the interval between toilet breaks, it was determined that the average interval of the participants between toilet breaks during flight was 2:09 (sd 1:01). Both the median and the modus were 2:00 exactly. In contrast to what might be expected, when splitting up the results per age category, it could be seen that, except for the youngest age group, the interval time slightly increased with age (Figure 3-3).

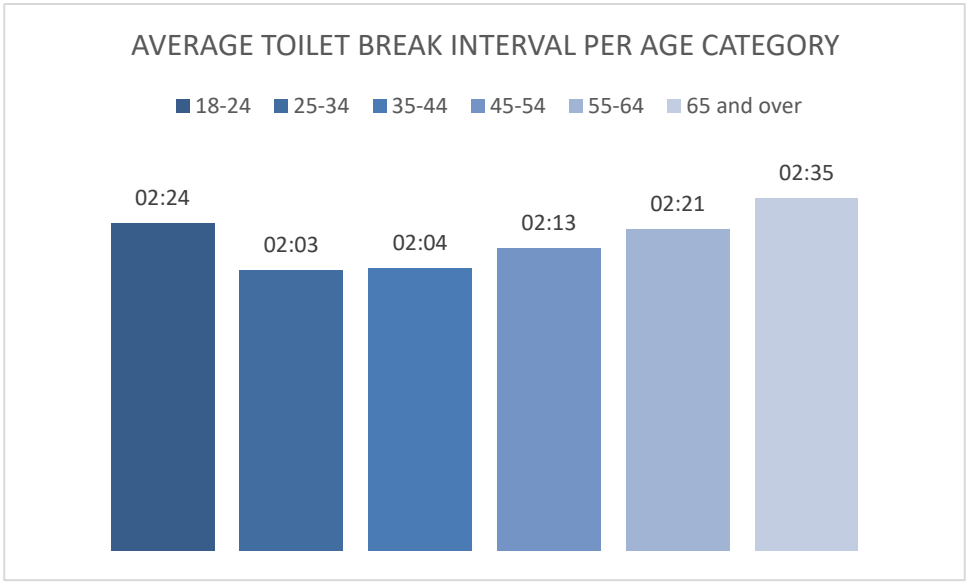

Figure 3-3. Average toilet break interval per age category (hours:minutes).

Out of 6300 responses to the question in scheduling of toilet breaks, it showed that 2097 (33%) participants scheduled their toilet breaks in a certain way. These pilots were subsequently asked what they do in order to schedule their breaks. A random 5% of the 2097 open answers were analysed and subsequently categorised.

In **Error! Reference source not found.**~~Figure 3-4~~ it can be seen that the largest part of the respondents (41%) with a strategy indicated that they have their toilet breaks during fixed phases of the flight or duty. A smaller part of the respondents with a toilet break strategy (17%) indicated that they wait to have their physiological needs until the workload during flight allows them to. 15% of the pilots indicated that they go to the toilet at fixed times (e.g. every two hours).

About 15% of the answers were related to drinking before or during flight; 7% of the participants limit drinking as much as possible to prevent using the toilet (too often), and 8% indicated to apply a certain drinking pattern during the flight.

Other strategies mentioned were either based on practical considerations (6%), or difficult to categorize (6%).

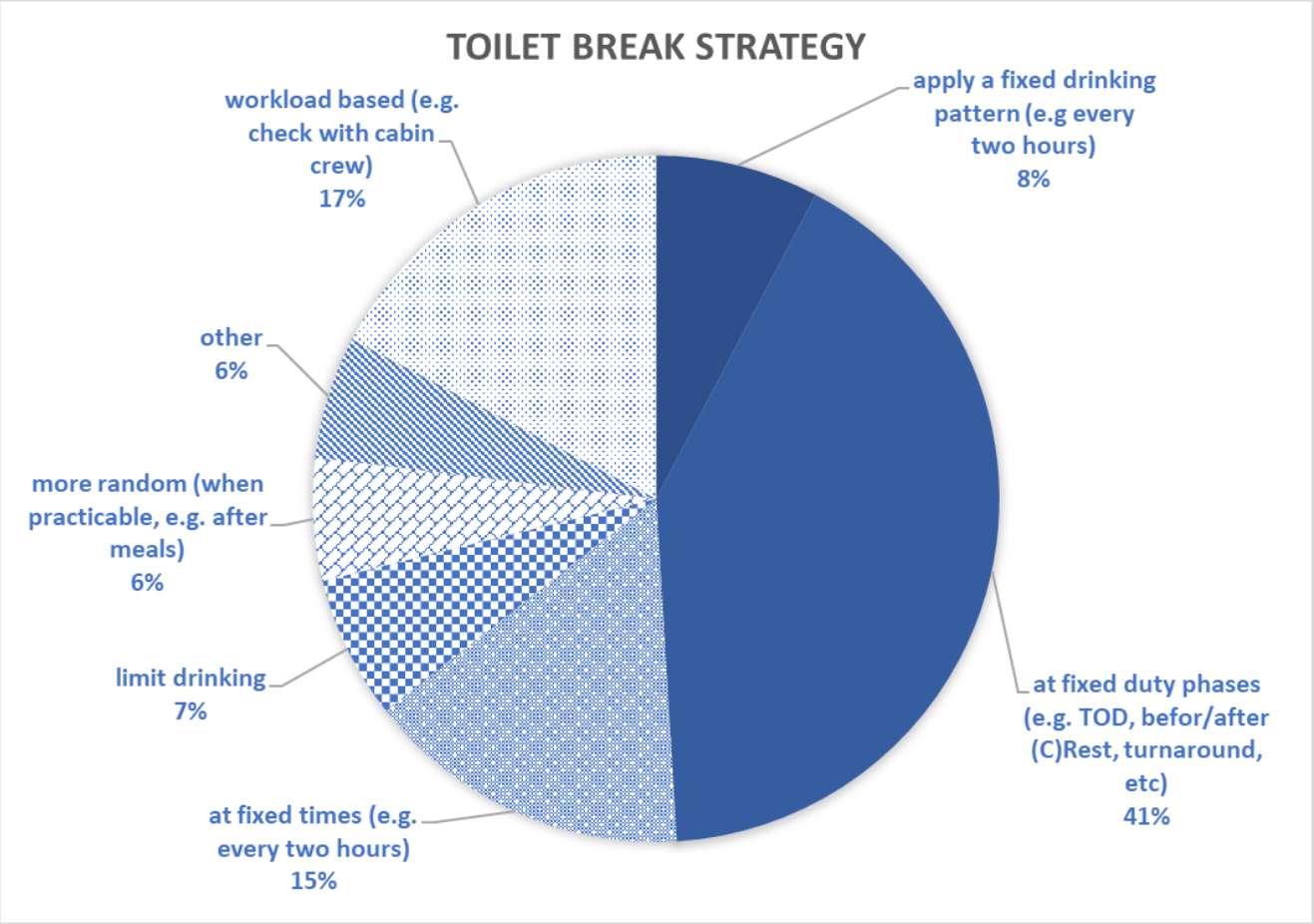

Figure 3-4. Categorised toilet break strategies as mentioned by the online survey participants.

3.4.2.1 Other remarks

To extract the most relevant answers to the open "other" question, a Latent Dirichlet Allocation (LDA) analysis technique was used. By means of this technique 14 distinct topics within the responses to the question were

identified. The method included cleaning the text and training a model to find the most relevant answers, and allowed to document concerns and viewpoints from more than 1500 text responses.

The main concern derived from the answers about physiological needs was that "to plan for sudden fatigue or physiological requirements during prolonged duties can negatively impact flight safety."

The most representative answers substantiating this concern proved to be the following:

- One respondent indicated that pilots are not machines: "you cannot tailor sleep patterns, physiological breaks etc to the extent which the authorities seem to expect, especially given everyone has different needs".
- Another respondent mentioned that it is necessary to have specific crew toilets in the aircraft: "we have problems when using the same toilets as passengers. Sometimes we have to wait for it around more than 10 minutes".
- Yet another respondent substantiated the cognitive issues concerning the urge to urinate: "I have experienced being alone in cockpit, or when colleague had controlled rest, that I suddenly needed to go to the lavatory. I found that it is hard to concentrate on the job when you feel the need to go to the toilet".
- Finally, someone mentioned the problems one can encounter with urgent needs during current operations already: "I have stomach problem from time to time, and if so I have had to go to the bathroom urgently. I am pleased to have a fit colleague on the flight deck when I am in the toilet, however, one time the first officer had to do a holding on the descend to give me some more time to come back".

3.4.3 Interviews with CAT pilots

In addition to the survey, four commercial airline pilots were interviewed on the topic of physiological needs and the proposed solutions, to get a more qualitative appraisal. All CAT pilots that were interviewed had previous experience in types of operation where the use of bladder relief solutions is more common (e.g. survey flights, General Aviation (GA), glider flying and military operation). The following comments could therefore be regarded as indicative statements of the feasibility of the results of the literature review, search for possible solutions, and the results of the survey.

3.4.3.1 Toilet breaks interval length and strategies.

The interviews emphasized the individual variation in habitual toilet break intervals. Whereas one pilot indicated that he never has problems with flights of 2 hours or shorter, another interviewee mentioned that he could refrain from a toilet break for flights of 4 to 5 hours as well, when having visited a toilet just prior to departure, but that he knew that mostly older colleagues have shorter toilet break intervals (although this does not coincide with the findings of the survey). Other possibilities mentioned to increase the time before going to the toilet is limit drinking during flights although one needs to watch out for dehydration and to avoid coffee as much as possible but drink water instead. It was also pointed out that, independent of what is physiologically possible in terms of toilet breaks, it is also important to get out of the chair occasionally, and stretch the legs. The interviewed pilots try to do this about every 2 hours.

3.4.3.2 Solutions for aircrew bladder and bowel relief

Most input of the interviewed pilots concerned the possible solutions that could be used by the PF in case of urgent need for bladder (or bowel) relief. Most of the interviewed pilots with GA experience indicated that they have used a disposable urine collector (e.g. a TravelJohn or a plastic bottle) on longer flights in the past.

However, multiple problems occurred as a result of this, such as iinterference with the flight controls (center stick), embarrassment (because of other people in the small aircraft), and temporary impairment (due to inability to answer e.g. ATC calls during the process, let alone handle non-nominal problems such as for instance an engine failure). Most of the interviewees were of the opinion that while urine collectors (and/or relief systems such as the AMXDmax) may be feasible in military operations, they would be unacceptable in commercial aviation. Only one of the interviewed pilots indicated that disposable urine collectors may be practically feasible in aircraft with a sufficiently large cockpit, as long as the autopilot could be engaged.

3.5 Review of accidents and incidents

The UK Air Accidents Investigations Branch (AAIB) website (https://www.gov.uk/aaib-reports) was used to search for aircraft accidents and incidents in the UK related to physiological needs. This dataset includes 11,184 reports (April 2024 status) on various types of aviation, including commercial and general aviation from 1958 onwards. The search applied resulted in one incident that was attributed to physiological needs. In 2011, a light aircraft crashed during final approach. The pilot commented afterwards that he had allowed his need to go to the toilet blur his concentration[3]. Although only one incident was found, it is possible that there have been fatal accidents as a result of similar scenarios. However, lack of concentration or any sort of impairment resulting from a need to go to the toilet cannot be determined post-mortem and can therefore not be identified as probable cause or contributing factor in the investigation of accidents that where fatal to the pilot.

A similar search in databases reflecting on military aviation accidents resulted in a few accidents that were related to the use of disposable urine collectors. In fighter aircraft, the use of disposable urine collectors is cumbersome due to the confined space and the need to unfasten the lap belts before use of the urine collector. Since the start of operations with the F-16 fighter in 1975, the USAF lost two F-16 aircraft (S/N 88-0461 in December 1990 and S/N 85-0451 in September 1992) due to interference of an unfastened lap belt with the side stick controller while the pilot used a urine collector in flight. The uncommanded control inputs resulted in both cases in loss of control. Fortunately the pilots were able to successfully use the ejection seat (Schultz & Schultz, 2021). The total number of USAF flight hours up to FY 2021 was 11,616,876[4]. Therefore the F-16 accident rate related to in flight use of a urine collector is 1.72×10^{-7} per flight hour. Because especially the confined space in an F-16 cockpit contributes to the possibility of this type of accident, it is not considered a realistic accident scenario for commercial air transport aircraft.

[3] AAIB Bulletin 11/2011, EW/G2011/06/09

[4] https://www.safety.af.mil/Divisions/Aviation-Safety-Division/Aviation-Statistics/

4. Discussion and conclusion

In this report the currently proposed suggestions for physiological breaks in eMCO CONOPs by OEMs was reviewed. In addition, a literature review was executed to describe the current scientific knowledge on the frequency and urge of human physiological needs (urination, defecation, bowel habits, menstruation) and to provide an overview of the solutions used in other domains. Next, the opinion of airline pilots was taken into account by means of both a widely distributed survey, and qualitative interviews. Furthermore, data on aircraft accidents and incidents related to physiological needs was searched in multiple accident databases.

Based on the outcomes of the survey it was shown that the average time in between toilet breaks of healthy pilots is a little more than 2 hours. From the literature it was also shown that it should be possible to have 2-3 hours in between. However, the results from the survey showed that large individual differences (e.g. based on age) exist in the time one can withhold from going to the restroom.

It is possible to some extent to schedule toilet breaks and drinking patterns, and the results of the survey demonstrated that some pilots do so. However, from the literature it became clear that a multitude of medical conditions regarding urination, defecation, and menstruation can cause an increased (and uncontrollable) urge to go to the toilet more frequent (and longer) than anticipated. The proposed eMCO segment duration of 2.5 hours as proposed by OEM2 could therefore cover the time between breaks for a large part of the pilot population, but will also result in relative frequent cases of the PF needing to go to the toilet before the end of the eMCO segment concerned.

It should therefore be anticipated that there will be occasions that the PF urgently has to use the toilet during the time period that s/he is scheduled to fly the aircraft during cruise flight. Causes for such occasions include unanticipated urination or defecation, nausea/vomiting, and menstrual care.

Existing methods for bladder and bowel relief of civil aircrew, who have to remain in the cockpit at the controls, were reviewed. All types of relief methods evaluated (diapers, urine collectors, relief systems, and diet interventions) proved not acceptable nor feasible to implement in eMCO operations, from both a medical and human factors point of view. Furthermore, based on the current medical ethical considerations and medical technical knowledge, it is improbable that an acceptable non-invasive method for bladder and/or bowel relief method for healthy individuals in a non-clinical setting could be developed in the coming decades.

Since withholding urination or defecation may lead to a deterioration in aspects of cognitive function, the PF should go to the toilet whenever needed during the EMCO segment. In that case (s)he would need to request the PR to take over, thereby disturbing the PR's sleep. Furthermore, as most probably the physiological urge will be high, it might not be possible for the PF to wait for the sleep inertia of the PR to be over. This would lead to a condition where the PF would need to be considered as incapacitated while the relief pilot might still be affected by some degree of sleep inertia. Either way, this situation would end the EMCO segment.

In conclusion, it must be accepted that commercial airline pilots sometimes have human physiological needs that need to be taken into account. In an eMCO operation, with only one pilot at the controls, this inevitability means that occasionally the eMCO segment must be terminated to address these.

5. References

ATSB (2016). Australian Transport Safety Bureau - Pilot incapacitation occurrences 2010–2014 https://www.atsb.gov.au/sites/default/files/media/5768970/ar-2015-096-final.pdf (accessed 09-02-2024).

BEA (2011). Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile. Incidents in Air Transport- Flight crew incapacitation. https://skybrary.aero/sites/default/files/bookshelf/3446.pdf (accessed 09-02-2024).

Berg RW, Buckingham KW, Stewart RL. Etiologic factors in diaper dermatitis: the role of urine. Pediatr Dermatol. 1986 Feb;3(2):102-6. doi: 10.1111/j.1525-1470.1986.tb00498.x. PMID: 3952026.

FSRH Clinical Guidance: Combined Hormonal Contraception; Faculty of Sexual and Reproductive Healthcare (January 2019 - amended November 2020) https://www.fsrh.org/standards-and-guidance/documents/ceuguidanceproblematicbleedinghormonalcontraception/.

Green R, James MR. "In-flight incapacitation survey," Aviation, Space, and Environmental Medicine, November 1991, Vol. 62, No. 11, pp. 1 068-1 072.

Griswold CA, Vento KA, Blacker KJ. Voluntary urinary retention effects on cognitive performance. Aerosp Med Hum Perform. 2023; 94(2):79–85.

Heaton KW, Radvan J, Cripps H, Mountford RA, Braddon FE, Hughes AO. Defecation frequency and timing, and stool form in the general population: a prospective study. Gut. 1992 Jun;33(6):818-24. doi: 10.1136/gut.33.6.818. PMID: 1624166; PMCID: PMC1379343.

Jousse M, Verollet D, Guinet-Lacoste A, Le Breton F, Auclair L, Sheikh Ismael S, Amarenco G. Need to void and attentional process interrelationships. BJU Int. 2013 Aug;112(4):E351-7. doi: 10.1111/bju.12224. PMID: 23879917.

Keller J. (2018). The CIA had a top-secret plan to keep the pilots of the world's most sophisticated spy plane from crapping in their pants at 70,000 feet. Task & Purpose. https://www.businessinsider.com/heres-the-cias-top-secret-plan-for-keeping-u-2-pilots-from-pooping-2018-10?international=true&r=US&IR=T (last visited 10-02-2024)

Lewis MS, Snyder PJ, Pietrzak RH, Darby D, Feldman RA, Maruff P. The effect of acute increase in urge to void on cognitive function in healthy adults. Neurourol Urodyn. 2011 Jan;30(1):183-7. doi: 10.1002/nau.20963. PMID: 21058363.

Lim KB. Epidemiology of clinical benign prostatic hyperplasia. Asian J Urol. 2017 Jul;4(3):148-151. doi: 10.1016/j.ajur.2017.06.004. Epub 2017 Jun 9. PMID: 29264223; PMCID: PMC5717991.

Mitsuhashi S, Ballou S, Jiang ZG, Hirsch W, Nee J, Iturrino J, Cheng V, Lembo A. Characterizing Normal Bowel Frequency and Consistency in a Representative Sample of Adults in the United States (NHANES). Am J Gastroenterol. 2018 Jan;113(1):115-123. doi: 10.1038/ajg.2017.213. Epub 2017 Aug 1. PMID: 28762379.

Pilmanis, A. A., & Sears, W. J. (Eds.). (1995). Raising the operational ceiling: A Workshop on the Life Support and Physiological Issues of Flight at 60,000 feet and Above (page 322).

Reynolds WS, Fowke J, Dmochowski R. The Burden of Overactive Bladder on US Public Health. Curr Bladder Dysfunct Rep. 2016 Mar;11(1):8-13. doi: 10.1007/s11884-016-0344-9. Epub 2016 Jan 23. PMID: 27057265; PMCID: PMC4821440.

Schrager S. Abnormal uterine bleeding associated with hormonal contraception. Am Fam Physician. 2002 May 15;65(10):2073-80. PMID: 12046776.

Schultz, M.C., Schultz, J.T. (2021) Female Relief Systems in U.S. Military Fighter Ejection Seat Aircraft. Journal of Aviation Technology and Engineering 10:2, 1–15.

Shapley M, Blagojevic-Bucknall M, Jordan K, Croft P. The epidemiology of self-reported intermenstrual and postcoital bleeding in the perimenopausal years. BJOG 2013; 120: 1348–1355.

Shokouhi N, Mohammadi S, Ghanbari Z, Montazeri A. Development of a new version of the Bristol Stool Form Scale: translation, content validity, face validity, and reliability of the Persian version. BMJ Open Gastroenterol. 2022 Dec;9(1):e001017. doi: 10.1136/bmjgast-2022-001017. PMID: 36564095; PMCID: PMC9791448.

Task and Purpose (2021). https://taskandpurpose.com/news/air-force-pilots-skydrate-piddle-packs/ accessed 09-02-2024.

Yang PJ, Pham J, Choo J, Hu DL. Duration of urination does not change with body size. Proc Natl Acad Sci U S A. 2014 Aug 19;111(33):11932-7. doi: 10.1073/pnas.1402289111. Epub 2014 Jun 26. PMID: 24969420; PMCID: PMC4143032.

Wrenn K. Dysuria, Frequency, and Urgency. In: Walker HK, Hall WD, Hurst JW, editors. Clinical Methods: The History, Physical, and Laboratory Examinations. 3rd ed. Boston: Butterworths; 1990. Chapter 181. PMID: 21250134.

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