Analysis of Ground Operator Errors

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ESTRACK, the European network of tracking ground stations, is remotely operated by a 24 h team located in ESOC, Darmstadt, Germany, called ECC team. In order to provide the requested tracking services the ECC team has to coordinate with several entities: the Scheduling Office, the satellite mission teams, the local maintenance teams and the external tracking service suppliers. The growing interest on human factors impacting space missions triggered the collection of related measures using ESTRACK service availability as initial case study. Since 2007 the ESTRACK incidents attributed to human errors of the ECC team and the interacting entities have been isolated for a dedicated analysis and investigation.

After an initial cleaning of the records, the paper describes the operational context of this collection of documented human errors and compares them against the volume of performed activities. A second classification discriminates between nominal and contingency operational scenario. The result is an uneven distribution of human error rate, mostly toward the execution of nominal procedures.

The core of the analysis consists of the driver identification for each human error. The drivers are grouped in two categories: endogenous and exogenous drivers ["Human Error: Cause, Prediction, Reduction", Senders and Moray, 1991]. The endogenous drivers are connected to the individual responsibility of the ground operator with respect to his/her responsibility and acquired knowledge. The exogenous drivers are related to external factors inducing the operator in error. Out of this distribution the three most accounted drivers (not following procedures, lack of attention, inadequate MMI) are discussed with examples and recovery goal.

This analysis provides the basis for corrective and preventive measures to prevent human errors in ESTRACK services, although the system and organisation evolution will present other new challenges to the operators. It will also constitute the methodological reference to analyse human errors of spacecraft operators.

I. Introduction

AMONG the various causes leading to space operations service interruption or degradation the human failure, commonly named human error, deserves a peculiar attention. Indeed the recovery measures to prevent such errors in the future are not easily and automatically identifiable. It is then worth to address the questions: why did we have this error? Which were the conditions surrounding this error?

A deep investigation of the context of the error allows to identify proper preventive and corrective actions, but it is not meant to remove the individual responsibility of the staff. The root cause of this family of service outages remains classified as human error, whatever are its identified drivers.

Such an analysis is recommended both in the scenarios of occurred significant impacts on the space mission and in the contexts of so far reported very minor consequences. It constitutes a powerful learning process on the effective integration between the system and its operators.

II. ESTRACK Operations

A. ESTRACK Network

One environment of space operations is the management of the interface space to ground, in particular the spacecraft tracking services provided by the ground stations and their relevant control centre. ESTRACK is the ESA network of tracking ground stations, remotely operated from the ESTRACK Control Centre (ECC) at ESOC in Darmstadt, Germany. The core ESTRACK network currently comprises 10 stations located worldwide. Their main

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duty is to interact with the various spacecraft by up-linking commands, downloading scientific data and housekeeping information and gathering radiometric data. The ESTRACK Core Network typically provides over 45,000 hours of tracking support each year, with 99% of service availability. The ESTRACK system is complemented by commercially operated stations provided thru service contracts with SSC (Sweden) and KSAT (Norway). Additional ESTRACK Cooperative Network stations are provided on a resource-sharing basis by other organisations, including ASI (Italy), CNES (France), DLR (Germany), NASA's Deep Space Network and Goddard Space Flight Centre and JAXA (Japan).

B. ESTRACK Players

The process of ESTRACK operations during routine is focused on the activities performed by the ECC team, with the role of network controller. The ECC team is organised in shifts covering the daily 24 hours. The ECC operator on duty executes the ground operations according to the timeline prepared by the Scheduling Office. Several satellite missions, especially the Low Earth Orbit ones, are now implementing an automatic execution. In some cases the monitoring of the automated operations is not requested. In all other cases the operations are manually executed, according to validated procedures. Real time interactions occur nominally with the Flight Control Team (one dedicated team per every flying mission) and with external stations operators.

The schedule prepared by the Scheduling Office is the integration result of several concurrent requests: the satellite missions, the network maintenance, and other auxiliary activities such as testing and training.

In summary the players of the ESTRACK network are: the ECC team (performing ground operations), the Scheduling Office (producing ESTRACK schedule), the Flight Control team (providing input to Scheduling Office and interacting in real time with ECC team), the local maintenance team at the station, the centre maintenance team at ESOC, the computer maintenance team at ESOC, the external station operators, the ground operations engineer (testing the station configuration and providing training), the ground station engineer (upgrading the ground station elements).

III. Ground Operator Errors

A. Anomaly Review Process

The process to review the anomalies relevant to the ESTRACK services is completely described in reference [3]. This ESA internal note has been recently updated to address the evolving needs of the organisation and to enlarge the scope of the process also to security failures.

The process foresees that all operational incidents relevant to the ESTRACK services are logged as anomalies in a dedicated database. The ECC team is the actual recorder of every incident, either noticed by themselves or reported by others, such as the Flight Control Team (e.g. no on-board lock) or external stations. The definition of operational incident includes all the events potentially impacting the successful provision of the ESTRACK services.

On a weekly basis the ECC Team Operations Supervisor has to filter the initial logged records in order to:

- Ensure completeness and clarity of the incident description and of the relevant workaround activities,
- Ensure precise definition and measure of impacted service (e.g. minutes of telemetry lost),
- Identify re-occurrences and link recurred incidents to a master record left open for investigation and resolution,
- Propose reasonable values for criticality of the incident and urgency for the resolution of the underlined problem,
- Highlight incidents caused by human errors,
- Propose records for closure.

The resulting table of weekly incidents is distributed to all missions operated in ESOC. The incidents with actual impact on the services are reported in a public weekly operations debriefing meeting.

An ESTRACK Anomaly Review Board (ARB) is appointed to review the anomaly records. As permanent members, the ESTRACK ARB includes the Ground Operations Manager, the ECC Team Operations Supervisor, the Integrated Logistic Support Manager and the Product Assurance Representative.

On a weekly basis the ESTRACK ARB meets to perform the disposition of the records, in terms of:

- Requesting feedback on specific incidents to relevant domain experts,
- Escalating incidents without explanation to a problem database for investigation,
- Reviewing records proposed for closure,
- Reviewing received feedback on assigned actions and deciding on the follow-on steps.

Specifically the incidents acknowledged as caused by human errors are escalated to a separate database for deeper investigation. A reduced board composed of the ECC Team Operations Supervisor and the Product Assurance Representative is in charge to analyse the context of each human error and to identify its drivers. This board meets every two months to perform the disposition of the records, in terms of:

- Verifying the correctness of the incident root cause as human error,
- Identifying the main driver of the human error,
- Assigning preventive or corrective actions as needed,
- Reviewing received feedback on assigned actions and deciding on the follow-on steps.

B. Records on Ground Operator Errors

Since the start of the review process (May 2007) up to April 2012 a total of 243 records have been collected in the dedicated database. The records that have gone through the complete review process and that have been closed are 213, whereas 29 have been rejected as wrongly assigned to this dedicated database. At the end of April 2012 only one record is left in the pipeline of the process with an investigation action to complete. The closed records confirmed to be incidents caused by human errors are 202. The other remaining 11 records have been finally classified as incidents caused by either incorrect procedure or failure of the system. As a final point the board concluded that 5 records out of 202 do not have sufficient information to allow for a reasonable identification of the human error drivers. This adds up to a total of 197 valid records over a time scope of 5 years.

C. Human Failure Rate

How frequent is the ground operator error?

Before calculating the human failure rate it is worth to remind the context of the work load relevant to ESTRACK services. For systematic routine operations the amount of controlled satellites at the beginning of 2012 was 14 (3 in LEO), 15 in 2011, 11 in 2007.

Over this period of 5 years (i.e. 60 months) a total of:

- 94,855 passes have been taken
- 6,973 service incidents have occurred.

As an example, during the month of August 2011, the ECC Team has taken 1,884 passes. With respect to the scheduled timeline the following has occurred:

- 1,153 passes were nominal (61.2%)
- 365 passes had operational contingencies requiring real time support (19.4%)
- 352 passes had schedule contingencies requiring manual intervention (18.7%)
- 3 passes have been rescheduled to other terminals or spacecraft (0.2%)
- 1 pass has been cancelled (0.1%)
- 10 passes have been added on mission request at last minute (0.5%).

Assuming that all collected human errors (i.e. the 197 valid records) are similar and no pending records are still to be processed, the frequency of ground operator error in the ESTRACK services can be calculated with respect to different scales:

- Calendar time: 3.4 human errors every month (i.e. $4.56*10^{-3}$ failure rate);
- Volume of ground operations: 1 human error every 482 passes;
- Amount of ESTRACK incidents: 1 human error every 35 incidents.

The failure rate of $4.56*10^{-3}$ is relevant to the entire process of ESTRACK operations. Apparently it fits with both the old [2] and the more recent [1] references, where a value between $1*10^{-3}$ and $1*10^{-2}$ is estimated as human error probability for routine tasks to be performed with care.

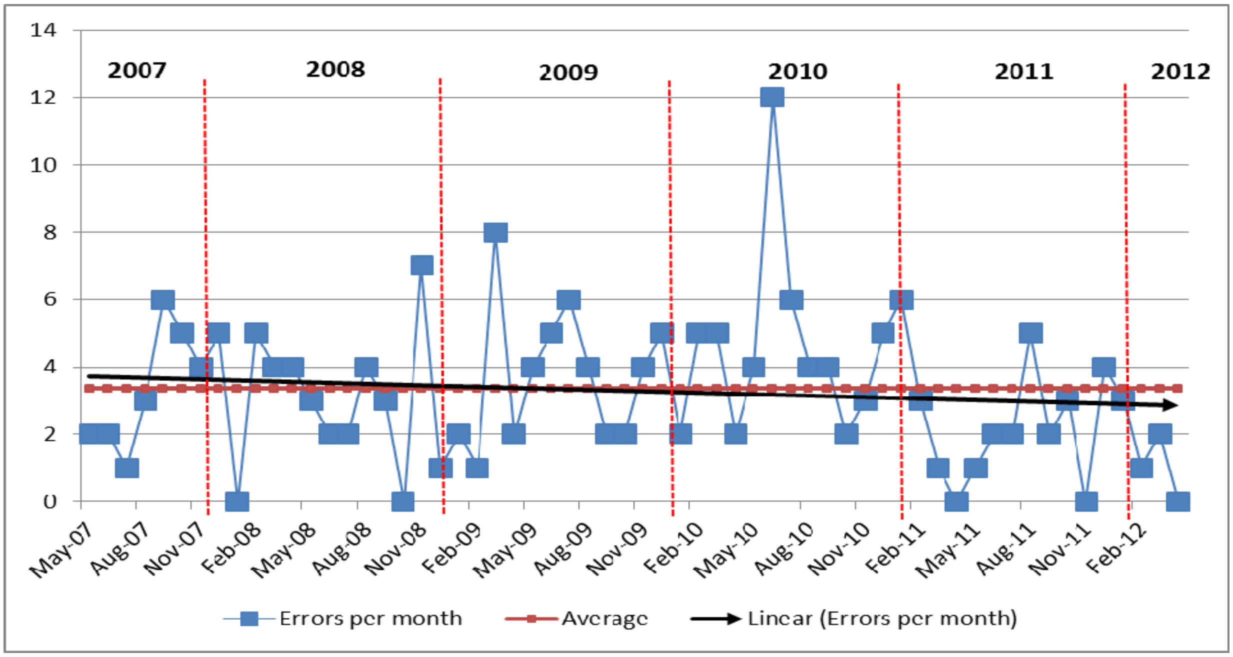

Figure 1. Error Occurrence over Time.

The analysis over time shows an apparent random distribution around the average value of 3.4 human errors per month with a dispersion of about ±2.2 errors (see Figure 1). The overall trend is decreasing below the average value. Indeed in the last 12 months almost all the values are below the average.

In terms of calendar years, with no doubt the worst year was 2010 with 40 recorded errors (see Table 1).

Year	Error	Percentage
2007 (only 8 months)	28	14%
2008	22	11%
2009	32	16%
2010	40	20%
2011	19	10%
2012 (only 4 months)	6	3%

Table 1. Distribution per Calendar Year

Considering the consequences of these human errors, the typical operational impact was the loss of a scheduled satellite pass, which often consists of scientific data lost. In the worst case one ground station was left not operational for two days, with adverse impact on several satellite missions. In any case no safety issue or mission critical issue was ever raised in these 5 years.

D. Distribution of Operator Errors

Who is responsible for these human errors?

Each record has been assigned for the responsibility of the human error to a specific player in the ESTRACK operations. As expected, the distribution of such responsibility indicates in the ECC Team the main contributor: 67%. All the other players provide a minor contribution. As an example, 9.6% is due to the local Maintenance and Operations Team at the ground stations, 5.1% to the Scheduling Office.

E. Impact of Introduced Changes

Which events may have impacted on the occurrence and on the frequency of ground operator errors?

An effort has been made to correlate the occurrence of human errors with specific changes introduced in the work environment and work load.

In terms of non-routine operations the following major events occurred in this period:

- LEOP operations: GOCE (March 2009), Herschel (May 2009), Planck (May 2009), Cryosat-2 (April 2012)
- Special operations: Rosetta swing-by and fly-by, ERS-2 de-orbiting (2011)
- Third party support: Phoenix, Chang'E1, Chang'E2, DAWN, Helios-2B, Ariane-5, ATV-1, ATV-2, Soyuz, Galileo IOV-1.

It is not possible to precisely correlate these special events with the occurrence of the 197 human errors during routine operations. At most it is observed that the four satellites launched between 2009 and the start of 2010 have triggered a new amount of routine operations, whereas just 2010 is the worst calendar year for occurrence of human errors.

Theoretically other possible changes could have played a role in the distributed occurrence of human errors, especially for the ECC Team: staff turnover, evolution of Man Machine Interface (MMI), re-organisation and update of ground procedures. Unfortunately such changes have been introduced so gradually that no substantial steps have been identified along the calendar. As a consequence, the absence of evident steps in the environment upgrade does not correlate with trend changes in the time distribution of occurred human errors.

IV. Drivers of Ground Operator Errors

A. Nominal and Contingency Context

The first analysis of the context of the ground operator error concerns which kind of scenario the staff was requested to operate: either a nominal scenario (i.e. absence of pre-existing incident) or a contingency scenario (i.e. driving presence of an incident requiring specific reaction, recovery or workaround). The board has classified each record for one of the two contexts.

The absolute distribution indicates 167 errors in nominal scenarios and 30 errors in contingency, which means a clear predominance of the first cases. However it is more appropriate to compare the results with respect to the volume of nominal and contingency operations. The month of August 2011 is taken as general quantitative reference to compare average monthly errors with actual passes (see Figure 2).

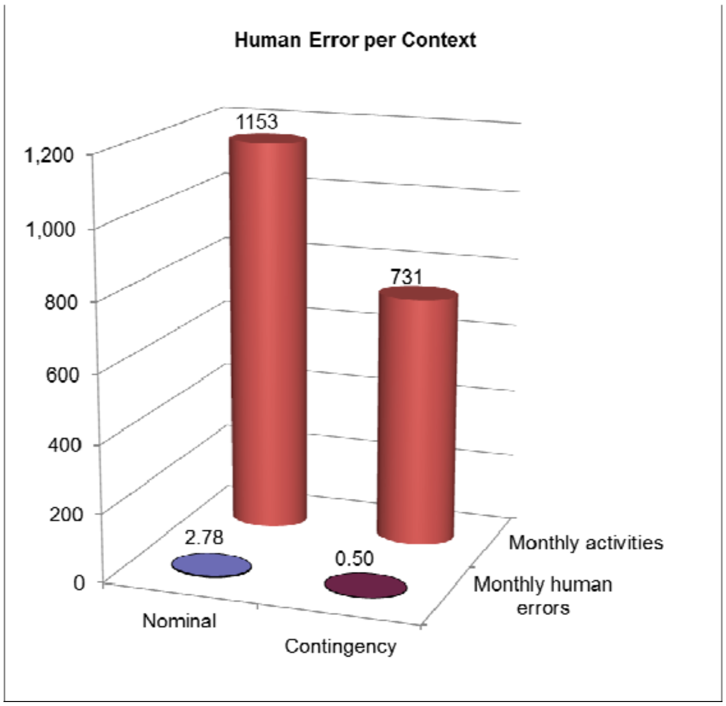

Figure 2. Nominal and Contingency Context.

In this frame the distribution indicates that the chance of human error in carrying out a nominal procedure (2.78 monthly error; 0.24%) is remarkably higher than the chance of human error when operating in a contingency environment (0.5 monthly error; 0.07%). This initial result suggests a higher level of concentration of the ground operator in presence of triggered alarms and a higher conformity in following the defined procedures. Conversely the day to day repetitive tasks may induce shortcuts and omissions. Note that a significant amount of human errors in contingency scenarios (23%) is committed during corrective maintenance tasks by the maintenance team.

B. Role of Individual Responsibility

The analysed drivers leading to human errors have been classified in two categories, discriminating around the individual responsibility of the ground operator. With respect to reference [1] the first class embraces the endogenous drivers, the second one is about the exogenous drivers.

The identified drivers based on the individual responsibility are:

- Lack of attention in performing a procedure (e.g. information not noticed, wrong value selected, typo introduced)

- Not following the steps of an existing procedure (e.g. missing the final step)
- Not following recently assigned verbal instructions (e.g. forgotten directives from previous shift).

The identified drivers external to the individual responsibility are:

- Inadequate communication over an operational interface (e.g. not effective language over the voice loop)
- Insufficient effectiveness of the Man Machine Interface (e.g. traps in the display in terms of colours, position, labeling)
- Inefficient organisational coordination with colleagues (e.g. not clear allocation of responsibilities)
- Insufficient received training (e.g. staff not prepared to expected complexity).

The human errors performed by external organisations could not be investigated. Therefore a generic driver "external" has been defined to cover such cases.

C. Distribution of Drivers

The board has classified each human error according to a prime identified driver. In some occasions also a second driver has been added just to complete the description of the context.

The endogenous and exogenous drivers have a distribution of human errors as reported in Table 2. In the context of ETRACK ground operator errors it is evident the predominance of the endogenous drivers (75%) over the exogenous ones. This means that only in limited cases (20%) the incorrect behavior of the operator can be induced by factors that he/she cannot control. A graphical way to represent the results of this analysis is the Ichigawa fishbone chart.

Driver	Error	Percentage
Not following procedure	83	42%
Lack of attention	64	32%
Not following verbal instructions	2	1%
MMI design	14	7%
Communication	12	6%
Training	9	5%
Organisation	4	2%
External	9	5%

Table 2. Distribution of Drivers of Human Errors

The identification of the different drivers has triggered the definition of adequate preventive measures to avoid possible re-occurrence in the future. One driver however ("lack of attention") gathers the cases where it is particularly difficult to isolate effective counter-measures. In any case specific details on preventive actions have been reported in each record. A further assessment has been performed by the Quality function of the company providing the ESTRACK operations services in ESOC. The Quality function also monitors internally the complete implementation of the preventive measures and updates the performance indicators of the ESTRACK service.

D. Comparison with Other Classification

A different perspective on the classification of human failures as described in reference [1] has been taken as reference for a separate analysis.

The model of human behaviour in reference [1] addresses the level of consciousness and automatism associated with a given action.

- Skill based action: it requires limited conscious attention as it is very familiar;
- Rule based action: it is infrequent, but it is addressed by rules and defined procedures;
- Knowledge based action: it is an unusual condition where no specific procedure is available.

Accordingly the human errors can be classified as:

- **Slips**: action performed not as planned (physical errors). Examples: pressing the wrong button, performing an action too soon/too late, omitting a step, over-performing a task, performing a task in the wrong direction, performing the right action but checking on the wrong object.
- **Lapses**: low level cognitive errors (failures of memory). Examples: after interruption restarting a procedure from a wrong step, forgetting what object to collect.
- **Rule-based Mistakes**: incorrect implementation of infrequent procedures. Examples: misdiagnosis leading to wrong procedure, wrong implementation due to non familiarity of the scenario.

- **Knowledge-based Mistakes**: wrong problem solving in an unusual situation. Examples: failure to assess or to analyse or to take decision.

In all these situations the individual genuinely believes to follow the correct course of action.

Instead of the error, the violation is a deliberate infringement of rules, but does not include sabotage and vandalism. Indeed the kind of deviation addressed in this analysis is non-malevolent.
According to reference [1] the violations can be classified as:

- **Routine**: deviations occurring as normal work practices.
- **Situational**: deviations occurring under particular circumstances (e.g. under time pressure).
- **Exceptional**: deviations occurring in unusual and emergency situations.
- **Optimising**: deviations introduced to make the work more exciting.

In all these situations the individual is aware to break the rules.

An off-line analysis of the collected records according to this classification provides the results reported in Table 3. This "a posteriori" analysis has the drawback of being conducted far away from the occurred event: therefore the classification is not as reliable as the one systematically performed by the board. Obviously incidents caused by external operators cannot be associated to any category.

A mapping between drivers and cognitive mistakes has been drafted as general guideline for the analysis:

- Lack of attention: slips, lapses
- Not following procedure: slips, lapses, rule-mistakes
- Not following verbal instructions: lapses
- Communication: knowledge-mistakes
- Training: knowledge-mistakes
- Organisation: rule-mistakes
- MMI design: slips, lapses.

Human Failure	Events	Percentage
Slips	68	35%
Lapses	53	27%
Rule-based Mistakes	51	26%
Knowledge-based Mistakes	15	8%
Routine Violations	0	0%
Situational Violations	1	1%
Exceptional Violations	0	0%
Optimising Violations	0	0%
External	9	5%

Table 3. Distribution of Mistakes and Violations

The results confirm the absence of deliberate deviations from written rules, as the overall ESTRACK process is mostly based on validated procedures. Preponderant are the accidental mistakes (slips, 39%), those based on lack of memory (lapses, 27%) and those arising during infrequent procedures (rule based-mistakes, 26%). As final consideration, few are the cases of mistakes in deciding the correct way forward in unusual contexts not covered by procedures (knowledge-based mistakes, 8%).

E. Major Drivers

Some of the identified drivers are worth more attention in order to specify a better preventive action.

The driver "Not following procedure" is very often present in the case of operators so used to perform an activity to believe to know the relevant procedure by heart. This may induce in shortcuts or in forgetting specific annotations in the written procedure. A very common case consists of missing the final step of a maintenance or test procedure, in order to bring back the system to its initial nominal status.

After all these incidents the staff get a reminder by the relevant manager and the quality function; moreover he/she has to follow a short refresh training.

In the category of "not following procedure" it happens also that freshly updated procedures have not been followed by the staff, still fixed to their previous version. These incidents demonstrate the need to better prepare the staff for introduced improvements with dedicated training.

Ideally speaking, the operator staff should be involved in the compilation of the procedures in order to increase their responsibility. In practice this job is covered by the ground engineers. A mechanism is in place to collect comments and improvement suggestions from the operators.

The goal for preventive actions on the driver “not following procedure” is to have a skilled operator in every circumstance.

A second important driver is the “lack of attention”. In most of the cases the reason behind the lower concentration of the staff during these incidents is the perception of a monotonous job and in the repetitiveness of the routine tasks. Actually the lack of attention occurs also in contingency scenario, not just in routine.

In few other cases some health factors have contributed to this driver such as tiredness, sickness conditions or missing regular eye examinations.

Ideally speaking, to raise the attention of the operator, especially when on shift for routine activities, it would be worth to add a kind of pressure, either motivational or with independent monitoring. In practice the staff is reminded to avoid this distraction in the future and it is accepted that no further action is necessary.

Indeed this driver is considered the most difficult aspect to counter-act with preventive measures. The goal for preventive actions on the driver “lack of attention” is to have a concentrated operator in every task.

It is much more easy to work on the exogenous drivers, in particular the training and the man-machine interface.

Training of the ESTRACK operator team is a continuous function. A person is appointed to keep track of the training records of all the operators on shift, to store and keep up to date the training material produced by the ground operations engineers, to fit the training sessions within the shift calendar and to manage the turn-over of the resources. The aspects more related to the analysis of human errors are the following:

1. Identification of individual training needs, starting from specific occurred incidents
2. Definition of general refreshing sessions for the whole team on specific topics.

Typically in the first category are all the incidents with drivers such “insufficient training” and “not following procedure”. The second category includes topics from the incidents with drivers “lack of attention”, “communication”, “organisation” and the identification of critical topics for regular recurring training. Because of this spread of scope against the identified drivers, it is commonly felt in ESOC that the training function is the most practical support against human errors in ground operations. Indeed the recent decrease of operator errors during last year is believed to be caused by the effectiveness of the ESTRACK training.

The other driver stimulating a concrete work is the man-machine interface, despite it is relevant to few records. In the design of an operator display the ergonomic compliance is not always the top requirement. This may result sometimes in the presence of traps for the operator (either working in a rush or loosely concentrated).

The first representative case is about the button “Acknowledge alarm” which was located just beside the button “Suspend schedule”. The mistake of clicking on the mouse when the prompt is not yet within the proper area of “Acknowledge alarm” but still in the adjacent area of “Suspend schedule” is causing the immediate interruption of operations. Unfortunately this kind of incident occurred twice before the display was positively improved.

Another case concerns the evolution of station configuration jobs to be launched. In the transition period the contemporary presence on the display of new and old procedures generated confusion in the operators, especially in keeping in mind which one was still applicable at that time. Again this trap induced few re-occurrences of the same mistake.

V. Comparison with Spacecraft Operator Errors

Up to now ESOC has not a formal mechanism to collect, analyse and react on human errors for spacecraft operators. Over the very long and successful operational history of the control centre nt a single spacecraft operator error had a significant impact on satellite missions. This is maybe the main reason for the absence of this specific process up to now.

A. Environment

The main difference between the ground stations operations and the satellite operations is the environment. For ESTRACK there is a single team managing a network of ground stations; this team belongs to a single contracted company. On the other hand for every space mission there is a dedicated flight control team located in a specific control room. The environment is therefore more composite for the entire frame of space operations, as it consists of a set of various teams, constituted of resources from different contracted companies. Each team follows the rhythm of the mission according to the orbit of the spacecraft and the relevant pass schedule.

In a future board appointed to analyse the human error in spacecraft operations at centre level it would be essential to have a leading spacecraft operator with contacts with all mission teams in order to investigate the various incidents. Contractual and personal issues shall be addressed with all affected companies. A training function shall be defined, with the possibility to baseline a common approach for several topics.

B. Tracking Issue

The major issue is the tracking of spacecraft operator error. During routine the spacecraft controller is used to work alone and to report major events from the pass in a log. He/She is not authorized to formally raise anomaly reports. This duty belongs to the spacecraft engineer assessing off line the log produced by the spacecraft controller, and in parallel the archived telemetry and the telecommand history. With this approach it is then felt that human errors could not be tracked systematically unless leaving evident traces in the recorded logs. On the contrary the capability to record also human errors with no operational impact would significantly contribute to understand the environment and the interaction with the operators.

As initial measure at the beginning of 2012, the marking of the root cause for spacecraft anomalies in all missions operated in ESOC has become a mandatory step before closing an anomaly report. It may sound a negligible step. However it reminds each mission anomaly review board that it is not sufficient to focus on the description of the operational recovery, but it is formally requested to identify the triggering event among a list of categories. Only when a record is classified with root cause “human error in operations”, then a more deeper analysis, like the one in place for ESTRACK operations, can start.

Looking at anomaly reports back to 2001 those classified as human error do not always provide enough details for an “a posteriori” analysis to identify their drivers. There are even some missions without any reported human error over several years of operations. Are they supported by a team of perfect operators? Unfortunately the information stored in these old records precluded to derive precise lessons learned and preventive actions at centre level. This confirms the importance of tracking not just the symptoms of the anomalous behavior and its resolution, but also the results of the investigation and the description of the mechanism for error triggering. At most from these historical records some statistics can be derived on their distribution over time and on their impacts on the mission.

VI. Conclusion

The described process of analysing human errors in ground operations for space missions is well consolidated in ESOC and active since 2007. For the overall ESTRACK operations process a human failure rate of $4.56*10^{-3}$ is the current estimate after 5 years of analysis, with a slight decreasing trend. In itself the value is very low when compared to the volume of performed activities: 1 human error every 482 taken passes. Moreover there is less chance of human error in contingency operations (0.07%), rather than in nominal routine operations (0.24%).

The identification of the drivers inducing the error of the ground operator allows to organise appropriate preventive measures such as targeted training, improvement of procedures, modification to man-machine interface. The analysis highlights the predominance of endogenous drivers (77%) in the distribution of errors, in particular “not following procedure” (43%) and “lack of attention” (33%). This result demonstrates the major role of the individual responsibility versus external factors. A parallel off line analysis on the same records, based on the level of consciousness and automatism inside the operator, reports also the absence of deliberate violations from procedures.

It is acknowledged that if on one side ESOC can improve some aspects to reduce the chance of human error in ESTRACK operations, on the other side the evolution itself of system, services and organisation may also increase either monotony and/or complexity, and at end may introduce new chances of errors.

The main recommendation for ESOC is to organise also a mechanism to collect and assess human errors during spacecraft operations. The challenge is not just to set up a dedicated database and a board to systematically review the records, but to ensure an adequate level of discipline in all affected teams to track the occurred errors, especially those without evident impact (e.g. in the recorded telemetry). Possibly a more sophisticated methodology to classify the errors, suitable for the characteristics of space operations, shall be introduced. Guidelines to identify and implement preventive measures shall be defined.

The fighting against human errors will be never-ending as by nature the human being is imperfect (and this includes beyond the operators also engineers and managers), but it is absolutely needed to contribute to successful space operations.

Appendix A
Acronym List

ARB	Anomaly Review Board
ASI	Agenzia Spaziale Italiana
CNES	Centre National d'Etudes Spatiale
DLR	Deutsches Zentrum für Luft- und Raumfahrt
ECC	ESTRACK Control Centre
ESOC	ESA Space Operations Centre
ESTRACK	ESA Network of Tracking Stations
JAXA	Japan Aerospace Exploration Agency
KSAT	Kongsberg Satellite Services
LEO	Low Earth Orbit
MMI	Man Machine Interface
NASA	National Aeronautics and Space Administration
SSC	Swedish Space Corporation

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