ADCSS 2016

FDIR OF AVIONICS ON EXPLORATION MISSIONS

www.sener.es

THIS PRESENTATION WILL LAST APPROXIMATELY:

A SKY FULL OF STARS (COLDPLAY)

+

MY WAY (F. SINATRA)

+

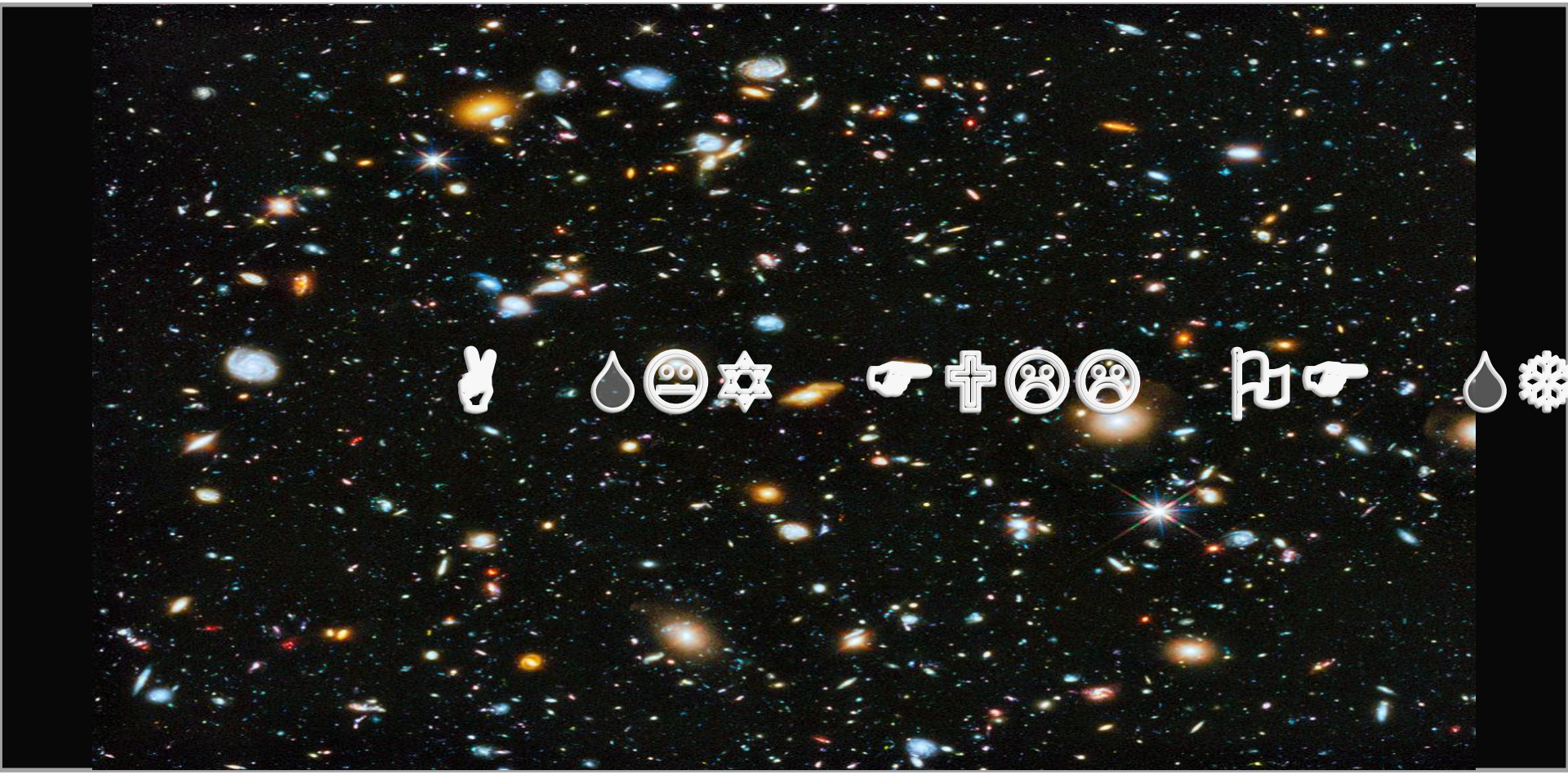
AQUARIUS – LET THE SUNSHINE IN (THE 5TH DIMENSION)

+

IF (FROM RUYARD KIPLING PLAYED BY SIR MICHEL CAINE)

TABLE OF CONTENTS

EXPLORATION: WHERE IS THE DIFFERENCE?



Exploration: Where is the difference?

What makes exploration missions **different** than other space missions ?

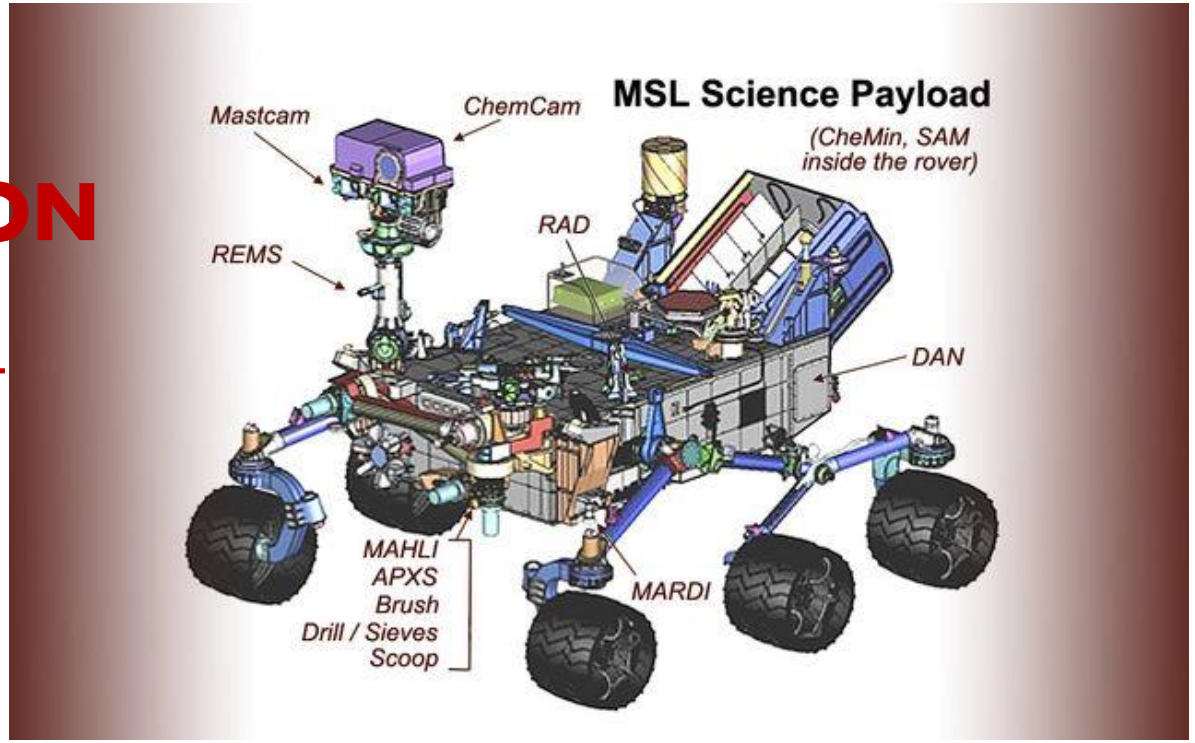
Exploration: Where is the difference?

FIRST

Experiments (**instruments**) and devices: number and **type**

INNOVATION

SCIENCE+

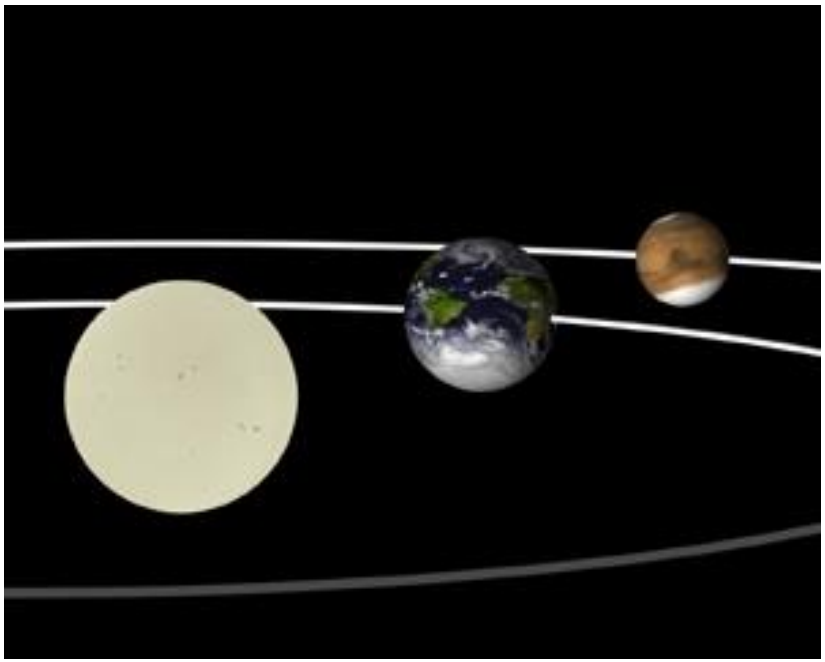


Courtesy NASA/JPL-Caltech

Exploration: Where is the difference?

SECOND

Ground connection



Credit to: NASA/JPL/Malin Space Science Systems

Signal travel time (round trip): from 7 to 45 minutes (Jupiter is 60 to 2 hour approx)

- **Limited time windows** (depending on whether it is DTE or via orbiter)
- **Limited time frames**

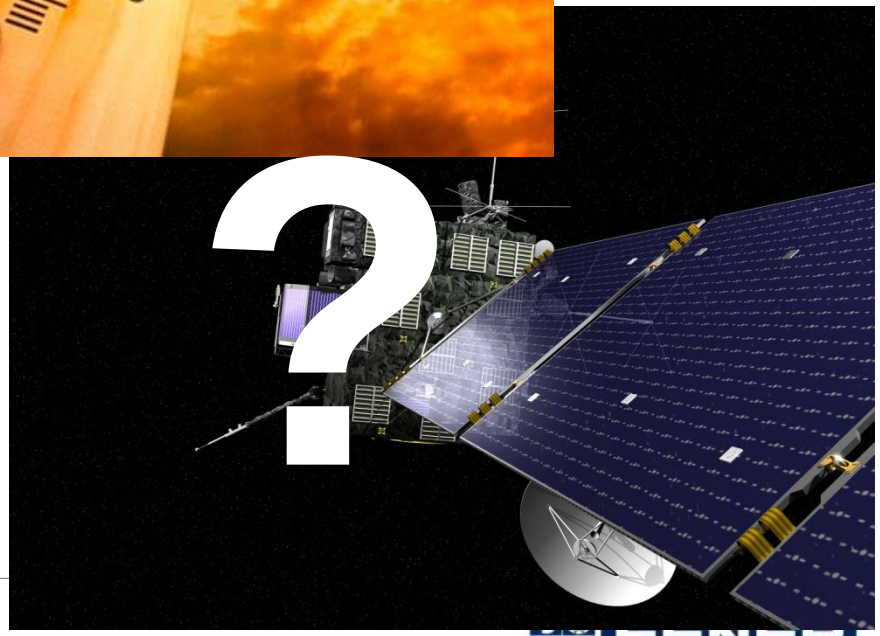
Exploration: Where is the difference?

THIRD

Environment:

Harsh conditions (temperature, wind, dust, pressure)

Sun availability (power availability)



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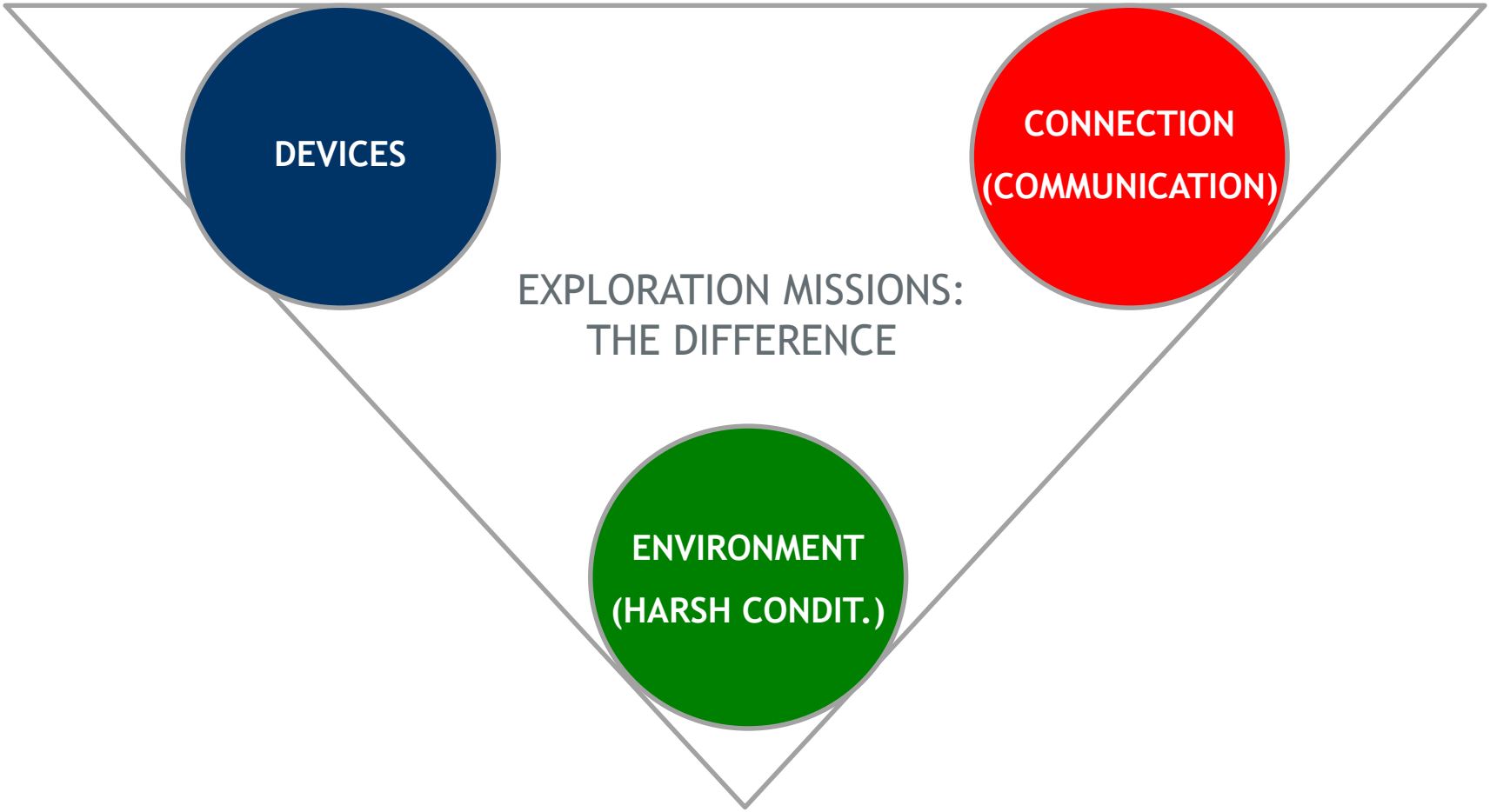


FDIR – A GLIMPSE ON THE CURRENT STATUS

MY WAY

(Frank Sinatra)

WHICH IS OUR WAY?

FDIR – A glimpse on the current status

Model-based approaches to FDIR

Alessandro Cimatti
Fondazione Bruno Kessler
cimatti@fbk.eu

- Fault trees
- FMEA tables
- Reliability measures

ADCSS Conference, ESTEC
FDIR Experience at Airbus

Gunther Lautenschläger
21. October 2015

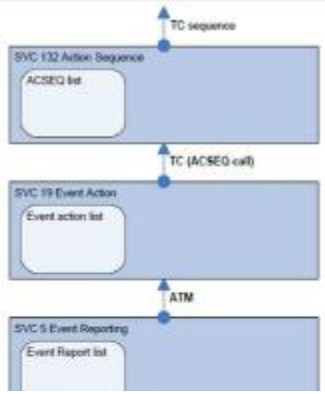
ThalesAlenia Space

FDIR - state of the art and evolutions

TAS-F point of view

JM. Pasquet – R. de Ferluc – A. Provost-Grellie
Dellandrea

ADCSS– 21 OCTOBER 2015



Find the sets of sensors that guarantee diagnosability

Adopt standard solutions for a FDIR reference architecture

FDIR is spread over spacecra subsystems & equipments

key factors to measure the FDIR complexity and related cost

HW and SW specific FDIR requirements

variance in the used Equipment's for … tailored FDIR solution

TRL

> FAME (Failure and Anomaly Management Engineering)
- Definition of the FDIR development methodology and associated V&V process
- Development of the Failure and Anomaly Management Engineering (FAME) Env toolset.

> FDI AOCS
- Improvement of AOCS, FDIR & Avionics for compliance with LEO de-orbit

> COMPASS
- develop a toolset for evaluation of system-level correctness, safety, dependabili the on-board computer-based systems.

FDIR

Need to harmonize FDIR concept

ADCSS 2015 – FDIR Session – 21/10/15

- Development of the Automated Model Generation Toolset for FDIR (AUTOGEF) and definition of the associated methodology. (Synthesize FDIR diagnosis and c system).

Low TRL

FDIR – A glimpse on the current status

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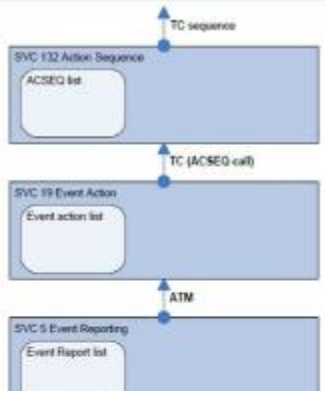

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AND ALL OF THIS TRANSLATES INTO…

FDIR – A glimpse on the current status

i. **Hierarchical approach**

ii. Configurable in

iii. Several studies

iv. Tools: FAME

v. Approach: A

vi. More focused o

vii. Focused on pos

viii. There is certain

FDIR LEVEL	Failure scope and effects
4	Failure on critical equipment or multiple failures or non localised failure Satellite goes to SAFE Mode
3	Platform: Failure at equipment or subsystem level Full mission objective cannot be ensured => potential reconfiguration
2	Subsystem:Failure at equipment or subsystem No need to transion the current satellite mode or configuration
1	Unit Level Internal failure recovered at the same unit

FDIR – A glimpse on the current status

i. Hierarchical approach

ii. Configurable in some cases (by using PUS services)

iii. Several studies and projects on several areas of FDIR implen

iv. Tools: FAME, COMPASS…

v. Approach: AFDIR, SMART-FDIR,… (casuistic and bayesian

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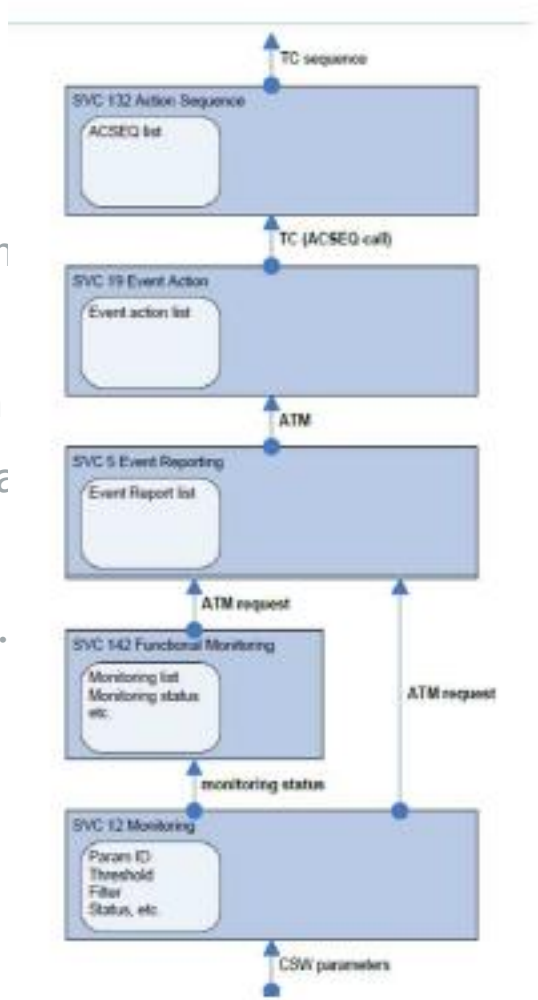
vii. Focused on post-mortem analysis

viii. There is certainly a knowledge on there, at some layer, but.



PUS services to support FDIR

TAS: State of the Art and evolution, ADCSS 2015

FDIR – A glimpse on the current status

i. Hierarchical approach

ii. Configurable in some cases (by using PUS services)

iii. Several studies and projects on several areas of FDIR implementation:

iv. Tools: FAME, COMPASS…

v. Approach: AFDIR, SMART-FDIR… (casuistic and Bayesian approaches)

vi. Some model based techniques for FDIR strategies are being initiated

vii. More focused on avionics rather than payload (although means are implemented)

viii. Focused on post-mortem analysis

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Extent of Fault Management in Space System – reflected in ECSS

1. ECSS-Q-ST-30C Dependability
2. ECSS-Q-ST-40C Safety
3. ECSS-E-ST-70-11C Space Segment Operability

ESA: FDIR engineering supported by ECSS, ADCSS 2011

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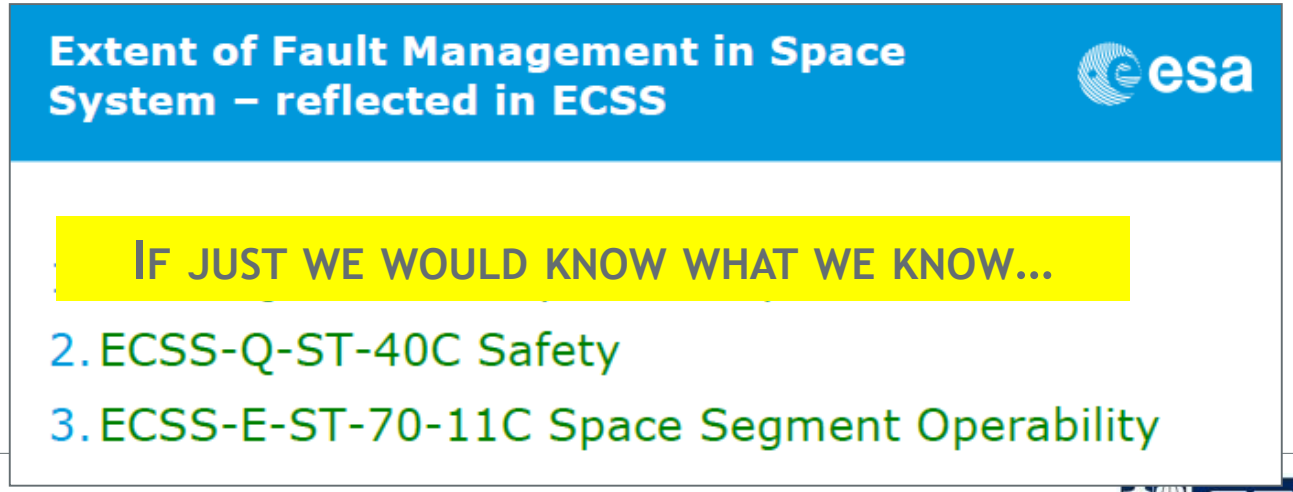

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BUT WHEN DOING A RETROSPECTIVE THIS IS NOT ALL...

FDIR – A glimpse on the current status

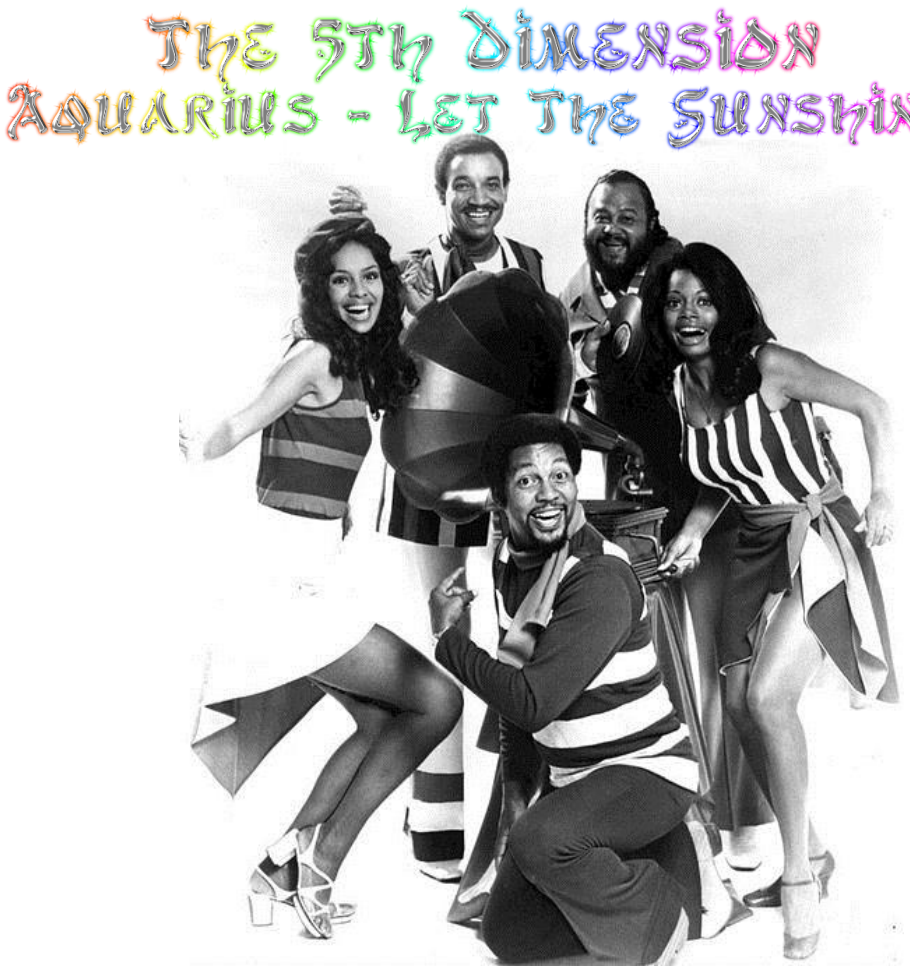
We may **lack of harmonization**, nevertheless

=> We use **similar approaches** (hierarchy, PUS…) for different missions

We dedicate devoted specification chapters to cover FDIR function (ref. MetOp SG Specs), and we do this much better than we use to

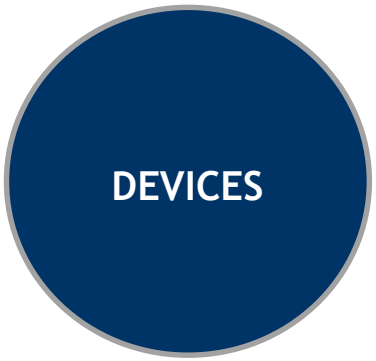
We request specific inputs for FDIR function when contracting an item

FDIR – Hints for the future



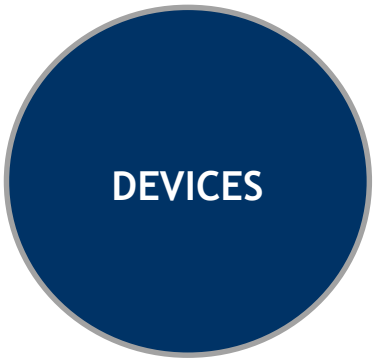
An inspiring song talking about an inspiring future.
This future, the Age of Aquarius, to occur after Jupiter is aligned with Mars.

FDIR – Hints for the future – SPREADING THE KNOWLEDGE



Are we sure that FDIR is understood at all levels of applicability (specially relevant for exploration missions)?

FDIR - Hints for the future - SPREADING THE KNOWLEDGE

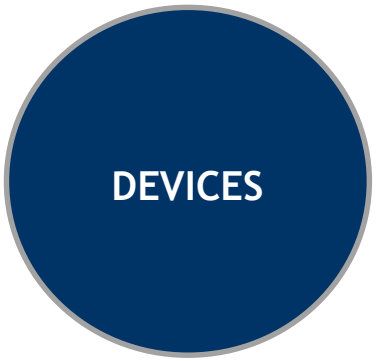


Are we sure that FDIR is understood at all levels of applicability (specially relevant for exploration missions)?

Different actors (units and instrument suppliers) involved => different background

Some of the on boarded devices come from institutes/universities/industries not so used to space technologies or to FDIR terms (DH terminology)

FDIR – Hints for the future – SPREADING THE KNOWLEDGE



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FDIR is not intuitive

FDIR knowledge is spread between **ECSS, papers and keynotes**

PUS Services are not intuitive

- ⇒ **Dedicated chapter on specs**
- ⇒ **Drawings** instead of text
- ⇒ Devoted sessions and topics on **Progress Meeting Agendas**
- ⇒ **Definition of FDIR lifecycle**

Shouldn´t we talk about Health Management System (HMS)

FDIR - Hints for the future - DATA

About the data manufactured on-board… Do we squeeze it?

FDIR - Hints for the future - DATA

About the data manufactured on-board… Do we squeeze it?

Credit to: http://www.formulaf1.es/

Telecommands: ~ 20 to 30
Telemetry Parameters ~150 to 300

FDIR - Hints for the future - DATA

About the data manufactured on-board… Do we squeeze it?

Credit to: http://www.formulaf1.es/

Including **HK & monitoring sensors** on board, whatever sensors, is **very expensive**

⇒ Why looking into them only in a post-mortem situation?

⇒ Why not taking benefit from this high amount of data?

FDIR - Hints for the future

About the data manufactured on-board… Do we squeeze it?

ENVIRONMENT (HARSH CONDIT.)

Actual item performance may differ from expected

Including HK & monitoring sensors on board, whatever sensors, is very expensive

⇒ Why looking into them only in a post-mortem situation?

⇒ Why not taking benefit from this high amount of data?

Diagnostic Log at high speed (ms frame) retrieved 1 minute (?) every X days

Data analysis from supplier

FDIR - Hints for the future - DATA

About the data manufactured on-board… Do we squeeze it?

ENVIRONMENT (HARSH CONDIT.)

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⇒ Why looking into them only in a post-mortem situation?

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Diagnostic Log retrieved 1 minute (?) every X days

Data a **SENSIBLE USE OF DATA BANDWITH**

=> **NOT THE ENTIRE DL CONTAINS USEFUL INFO**

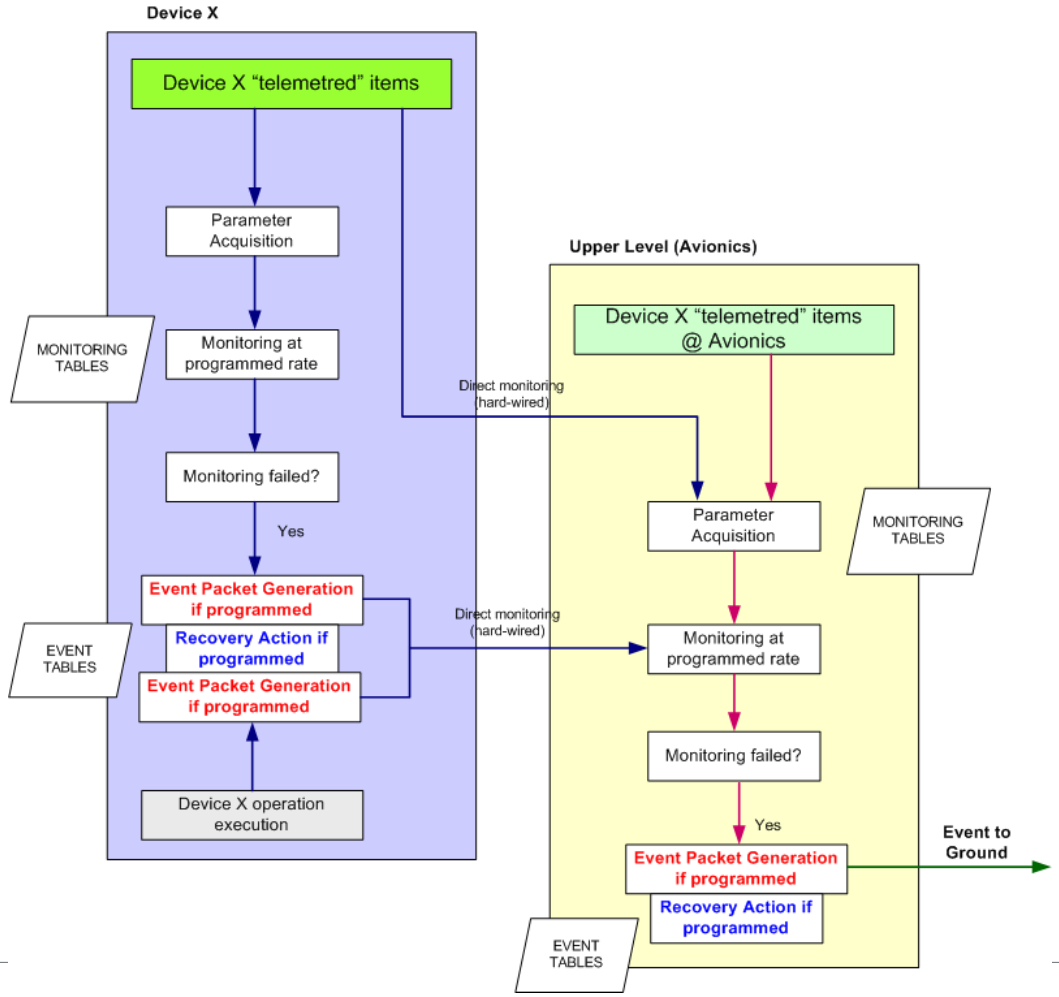
=> **COMPRESSION**

CONNECTION (COMMUNICATION)

SENER

FDIR - Hints for the future - DATA

What is beyond the use of PUS services used to build the FDIR function?



FDIR - Hints for the future - DATA

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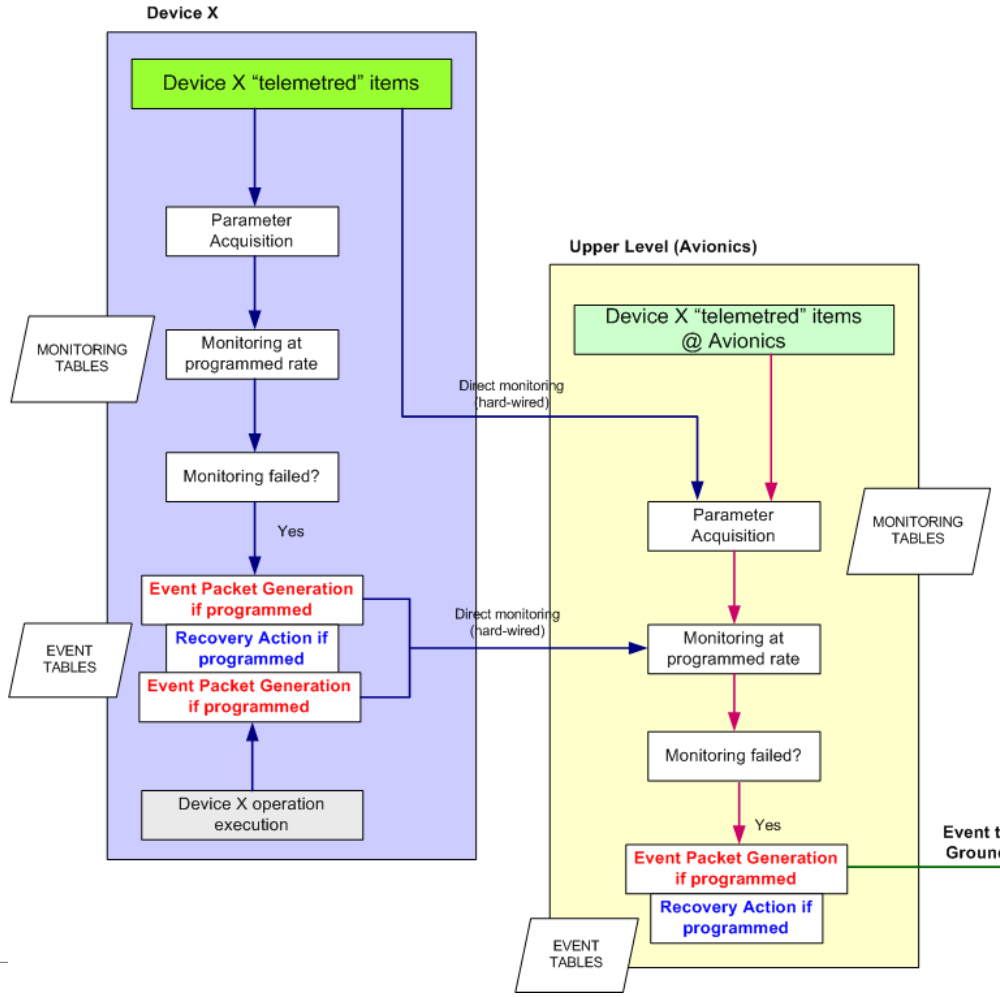


Flexibility via configuration LUTs

Scheduled Diagnostic Log possibility

+

ENVIRONMENT (HARSH CONDIT.)

=

Additional knowledge

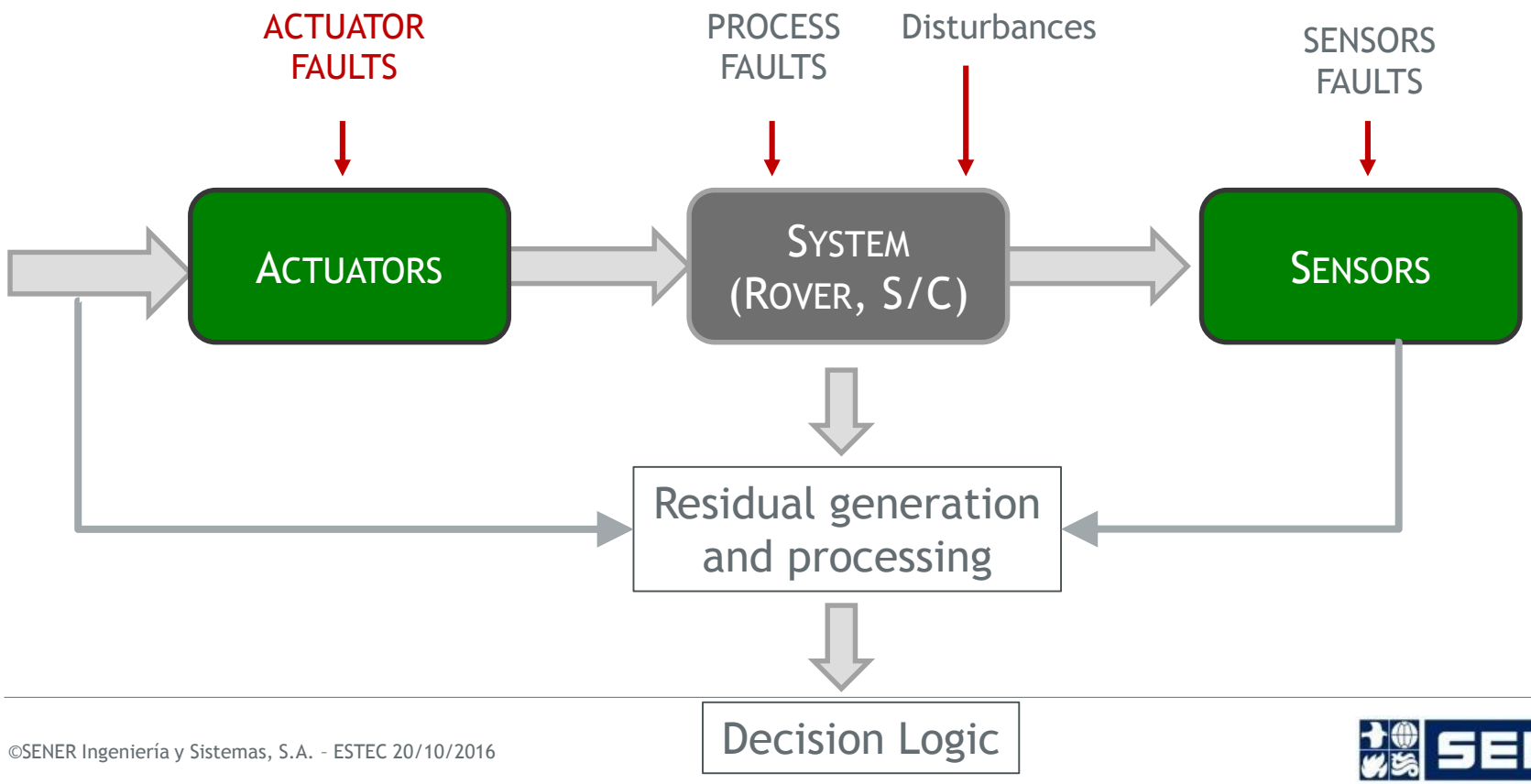
Ad-hoc FDIR configuration

FDIR - Hints for the future - DATA

A further step on squeezing the data: modelization

Modelization for FDIR development has achieved large great progress (COMPASS, FAME)

Question: would it be possible to provide on-board obtained data to test these models?



FDIR - Hints for the future - DATA

PUS SERVICES => BEST USE POSSBILE

PUS SERVICE 3 => DL => LET'S USE IT TO INCREASE OUR KNOWLEDGE:

- ⇒ **PRE-MORTEM ANALYSIS**
- ⇒ **END OF MISSION ANALYSIS (SUPPLIER ANALYSIS)**
- ⇒ **FDIR MODELS VALIDATION**

FDIR - Hints for the future - FDIR Concept

Is there a single FDIR strategy valid for all exploration missions?

Combined approach to be explored:

- Model based for the subsystems where dynamics plays an important role (AOCS, GNC).
- Classical approach for those subsystems/elements where steady state models would be useful (power…)

FDIR – Hints for the future – Way forward

From the previous slides some potential ideas to be explored (TRPs?) can be envisaged:

i. Developing of Model based FDIR systems oriented to GNC/AOCS => potential models library to allow re-use?

ii. Developing methodology for model-based FDIR system => building blocks?

iii. Data retrieval for post-mission analysis (large scale and ms scale)

iv. FMEA and HSIA as main inputs for building the FDIR solution TO INCLUDE TIME FRAME INFORMATION

v. Cost-benefit analysis

References

ADCSS 2015 – Presentations FBK, TAS, ASD

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P- Sivac & T. Schirmann

The Venus Express S/C System Design

J. Marzat, H Piet-Lahanier

Model-based fault diagnosis for aerospace systems: a survey

Robert FONOD (Thesis)

Model-based Fault Diagnosis and Fault Accommodation for Space Missions

D. Henry, C. Le Peuvédic

Model-based FDIR and Fault Accommodation for a Redezvous Mission around the Mars Planet: the Mars Sample Return Case

Thanks for the attention