The background of the slide is a deep space image featuring a dense field of stars and a prominent blue and purple nebula. A bright, multi-colored star is visible in the upper right quadrant.

**EE-584**  
**Spacecraft Design & Systems Engineering**

**Space Operations**

# Spacecraft Operations

learn to fly a spacecraft

# About the presenter

- MSc Aerospace Engineering, Delft University of Technology (2006)
- ISS-Columbus Module operations preparation (ESA-ESTEC)



- Planetary Mission Operations (ESA-ESOC)
  - Mars Express (and Venus Express / Rosetta)
  - Exomars 2016 - Trace Gas Orbiter and Schiaparelli Lander
  - Meteosat Second Generation
- Sentinel-3 Operations Service Manager (Eumetsat)



- Space Situational Awareness (Northstar Earth & Space)

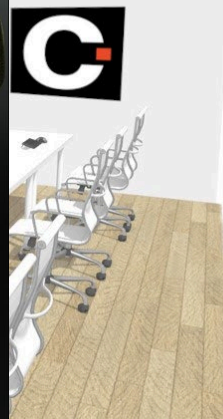


- ADR and IOS Product and Mission Operations (ClearSpace)





Reality



Expectation

# Mission or space operations

Activities related to the planning, preparations, execution and evaluation of the combined space segment and ground segment Operations

As soon (and simple) as possible

Driving design of system functions and performance requirements

## Ship analogy

Captain - Decide where to go and what to do

Navigators - How to get there, knowing where are we now

Planners - Convert activity timeline into a viable schedule

Sailors - Execute the day to day schedule, respond to all situations

Engineers - know the ship, including payloads, its performance and behaviour

**Sailors, planners, navigators and captain work in harmony with ship's engineers while it is designed, integrated and tested, to be able to sail safely and reliably**

## The people involved

Flight Operations Team – Execute Timeline

Ground Support Team – Keepin it connected

Flight Dynamics Team – Move and Point

Mission Support Team – Offline and backoffice

Industrial Support Team – “Switch OFF and ON”



Mission Operations Team

# Getting ready

## Design:

Establish Concept of Operations

Flow-down to ground and space functions

Create operability requirements and system level

Develop: Timelines, Rules, Procedures, Databases

Reviews: Are we on right track, fitting system design, on time and (will we be) ready?

Verify: Support to testing - procedures and databases Satellite and Ground tests?

Validate: Integrate all products, validate through architecture in facilities by operations team

Train: Nominal and anomalous scenarios cosplay before launch, internalising the process.



# Operational Products

In Flight Operations Plan

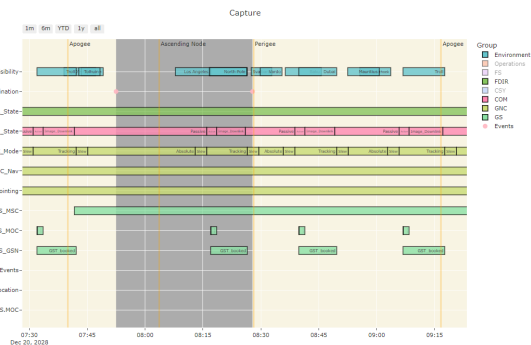
Governance

Rules

Processes

Timelines

Procedures



Software interface showing procedure information, including Section A: Procedure Information, Section B: Preliminary Steps, Section C: Body of the Procedure, and Section D: End Procedure.

Databases (Dictionaries)

Software Database

Flight Dynamics

Mission Database

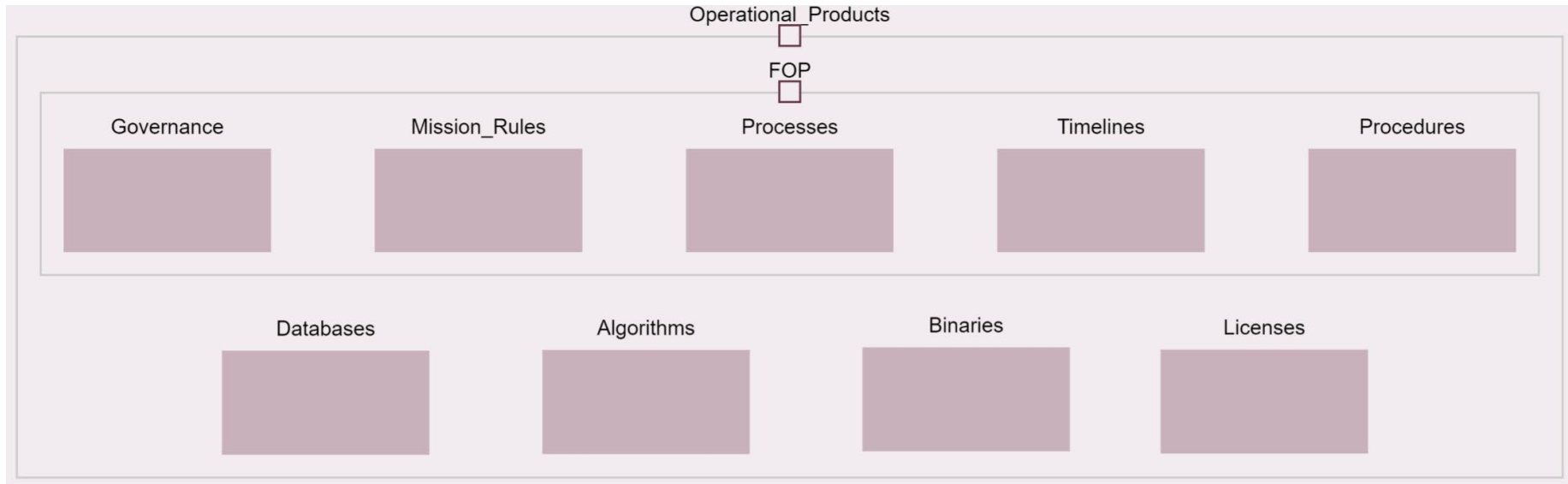
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Binaries and Algorithms (Software)

Licences (operate, launch, emit, receive)

# Operational Products



# Ground Tools

## Ground Segment

### Online Systems:

Monitor, Control, Plan, Archive, Process, Display, Automate

### Offline Systems:

Infrastructure (HW/SW), Facilities, Configuration, Security

### Ground Station Network:

Track, Receive, Transmit, Distribute

# Ground Tools

Mision\_Operations\_System

Archive

Monitor

Control

Plan

Process

Display

Automate

Mission\_Support\_System

Infrastructure

Facilities

Configuration

Security

Ground\_Station\_Network

Ground\_Station

Network

# Read the procedure

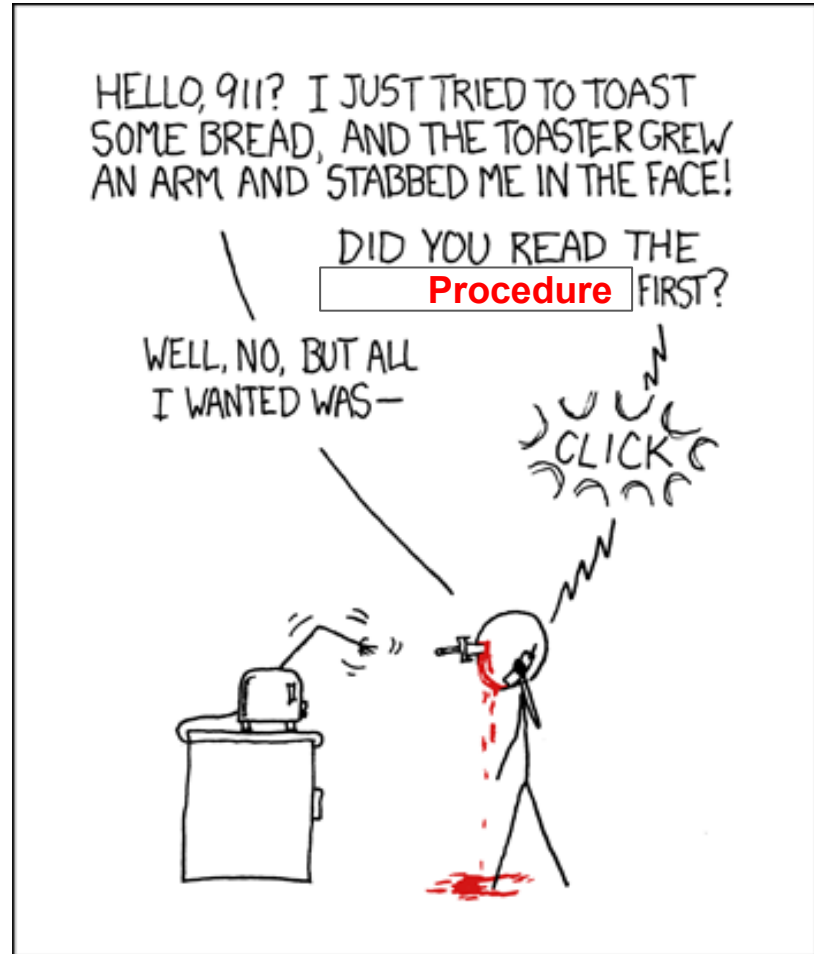
Follow instructions

Respect reporting lines

Log your work

Stop if unclear

Methodical approach to anomalies



# Trends impacting operations

## File Based Operations:

- More logical control over all data types ensuring integrity

- Closer to a regular file and operating system

## Automated Ground Segments

- Fewer manual functions, releasing brainpower and reducing team sizes

- Tools providing corrective maintenance

## Autonomous Satellites

- Different Interface to ground: “tell me when you need help” instead of “is it done it yet?”

- Operator as a babysitter instead of puppet master, enabling fleet management.

## OnBoard Processing, Inter-Satellite Links and Optical Direct-to-Earth

- Only downlink the interesting data, allowing quicker follow up tasking or downstream distribution.

- Orders of magnitude throughput and overhead enhancement

# The space sustainability factor

Adhere to standards (But which one...)

Be a good neighbour

Leave no trace

Free your place

Enable traffic management

Prepare to be Removed/Refueled/Repaired

Design for demise



SPACE  
SUSTAINABILITY  
RATING

ISO 24113:2023

Space systems — Space debris mitigation requirements

2021

Publication of Guidelines for Safe Close-Proximity Operations

IADC Space Debris  
Mitigation Guidelines

Fighting space junk: More than 100 partners sign Europe's 'Zero Debris Charter'



Platform for Shaping the  
Future of Mobility  
Space Industry Debris  
Statement

WORLD  
ECONOMIC  
FORUM

Standard interfaces for  
Design for Removal



# What can possibly (will definitely) go wrong

False Instructions: “Where was that +X band antenna pointing”

Wrong Databases: Closed/Open is 0/1, but which valve did we open

Badly Timed Safe Modes: “Hey! Was that our planet?”

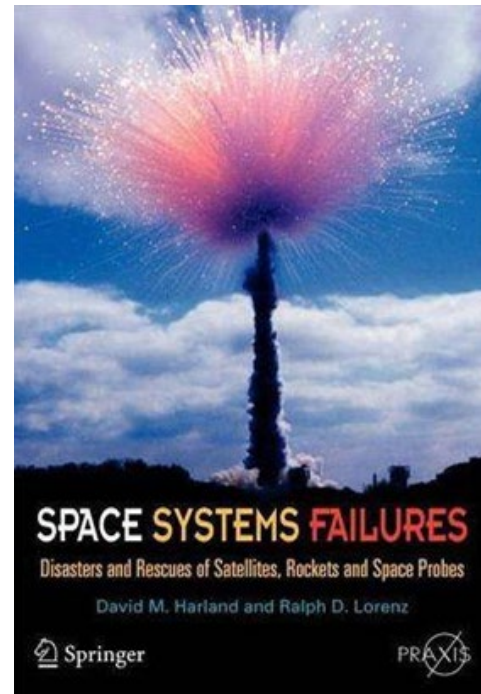
(AIT) Checklist: “This cable was meant to go to Mars”

## Notable Saves:

Stuck-in-the-middle Antenna Switch: “Let’s fry it”

(Ab)using systems for other purposes: Star trackers as imagers

Prop system leak: Slow dancing using the Reaction Control Thrusters



# Assignment

Compile a timeline and associated procedure for 1 of these three options

Topic 1 : Lunar orbit insertion of your GNSS asset

Topic 2 : Space weather event reception and alert distribution procedure

Topic 3 : Debris capture timeline

Objective A : Write a definition of done for this phase

Objective B : Create a logical procedure with steps and context

Order, duration, dependencies and handover criteria

cover the constraints on: Time, Exclusion, Power, Data, Staffing, Ground visibility, System redundancy (also ground systems)

**EPFL**

backup

# Operations nomenclature

Concept of Operations - High level mission description covering phases and users

Timeline - the visual breakdown of (part of) the concept of operations

Procedure - Logical breakdown of instructions to implement mission operations

Space-to-Ground ICD - Interface control document covering data interfaces from and to space

Database - Telecommand and telemetry protocol and constraint dictionary controlling (space) segments

Mission Operations Centre – aka MOC/MCC - the place from where system is controlled

Mission Operations Team - combination of ops/ground/flight/industry teams

Operational Concept - How the system is used to achieve mission goals

Operability - The tailoring of the system to the operational functional needs