GOMSPACE EXPERIENCE OF SAVOIR WITH THE JUVENTAS AND OTHER CUBESATS USING A TEST-DRIVEN DEVELOPMENT APPROACH

SAVOIR4Cubesats Workshop 2022

OUTLINE

- GOMSpace and CubeSat trends
- Where SAVOIR could help
- SAVOIR at GOMSpace

- Test-driven development approach

GOMSPACE AND SAVOIR

- Do we have a connection?

GOMSPACE AT A GLANCE

- **Globally leading manufacturer & supplier of nanosatellite solutions**
- **Founded in 2007 and listed at Nasdaq stock exchange in Stockholm (GOMX) in 2016**
- **+220 employees strong in DK, LU, SE and FR and USA**
- **Our strengths:**
  - Miniaturised satellites ready for constellations
  - Radio technology / software defined radio
  - Production capacity in place with +4000 products delivered annually
- **Our traction:**
  - Very successful in orbit validation program (GOMX)
  - Customers in more than 55 countries

GOMSPACE ROADMAP

2007

2018 - present

2023

2024

4th generation | 5th generation | 6th generation

GOMX4A/B, many commercial missions
In serial production

Technology

- 6U and 8U
- Inter-satellite linking
- SW-defined radio (SDR)
- Cold gas Propulsion
- Star-tracker

GOMX5, **JUVENTAS**, **CubeMap**, **M-ARGO**, commercial missions
Under development and implementation

Technology:

- 6UXL, 12U, 16U
- Electric Propulsion
- Wideband radio
- High power
- Increased autonomy
- New on-board computer
- Improved pointing performance

Commercial missions
Preliminary development

Technology:

- Microsatellite
- …

GOMSPACE CUBESAT TRENDS

5th generation → 6th generation

Market needs

- Reduce lead times
- Higher performance payloads
- High pointing performance
- Reliability and availability
- Mission lifetime increase

System technology trends

- Standardization
- Third party equipment and payloads
- 12U and 16U
- +100W power
- High performance AOCS
- Radiation tolerance
- Increased autonomy

OBDH technology trends

- Cubesat Space Protocol (CSP)
- Standardization of drivers and handlers
- CAN replacing I2C and SPI
- High performance OBC (Zynq)
- AOCS auto-coding
- SEE / SEFI (radiation) mitigation
- On-board procedures
- FDIR
- Fault tolerance / redundancy

WHERE SAVOIR COULD HELP

OBDH technology trends

- CSP
- **Standardization of drivers and handlers**
- CAN replacing I2C and SPI
- High performance OBC (Zynq)
- **AOCS auto-coding**
- **SEE / SEFI (radiation) mitigation**
- **On-board procedures**
- **FDIR**
- Fault tolerance / redundancy

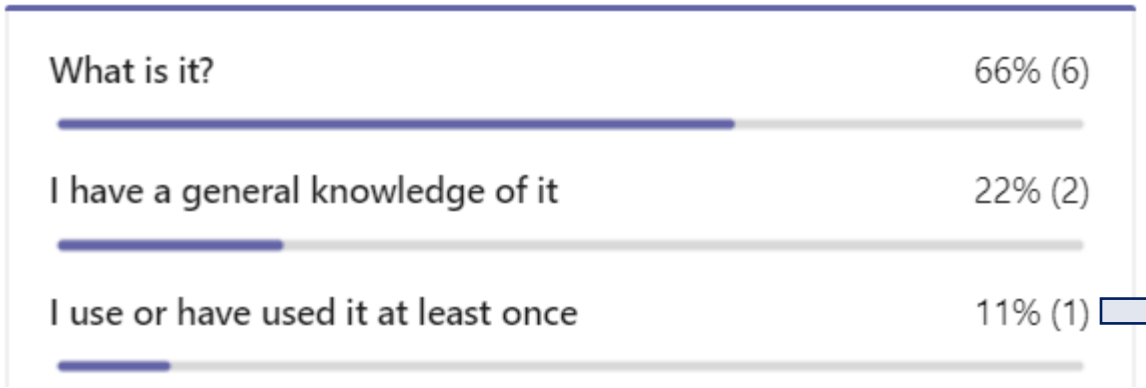
- Standard data structures for equipment?
- Lean SRDB standard? (not SCOS MIB!)
- **AOCS auto-coding handbook**
- SEE / SEFI (radiation) mitigation guidelines / handbook?
- On-board procedures handbook incl. interoperability?
- **FDIR handbook**
- …

Maybe a very good analogy:
ESA CubeSat IOD standard with tailoring of ECSS for CubeSats – very pragmatic and **usable**!

SAVOIR AT GOMSPACE

Survey among GOMSpace systems engineers:

What is your knowledge and use of SAVOIR?



Current uses at GOMSpace:

- SAVOIR-HB-005 **Automatic Code Generation** for AOCS & GNC Flight SW
  - Juventas AOCS
  - CubeMap AOCS
- SAVOIR-HB-003 SAVOIR **FDIR Handbook**
  - Juventas FDIR
  - GOMX5 and CubeMap FDIR (early phases)

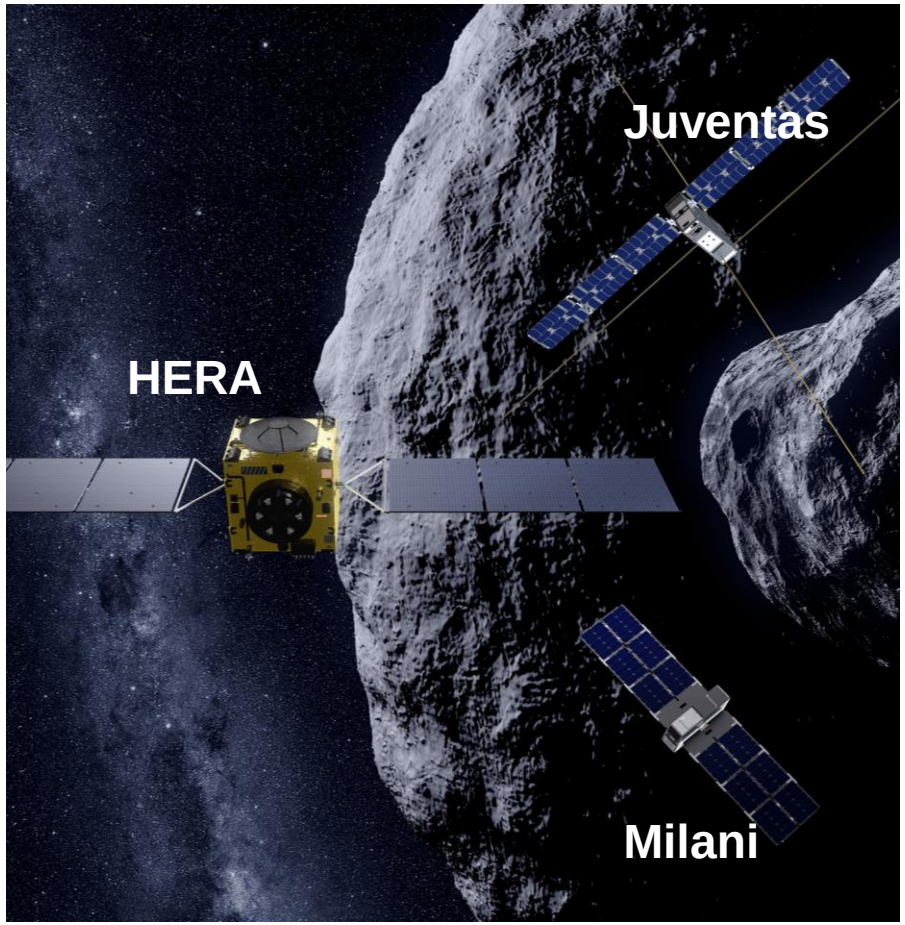
SAVOIR AT GOMSPACE

- Today SAVOIR has (unfortunately) a very limited exposure and use at GOMSpace
- New needs at GOMSpace, and probably other CubeSats
- A good time to engage CubeSat community with SAVOIR
- But, keep it pragmatic (Cubesat IOD)
  - CubeSats are allowed to fail (but somehow mostly they don’t)

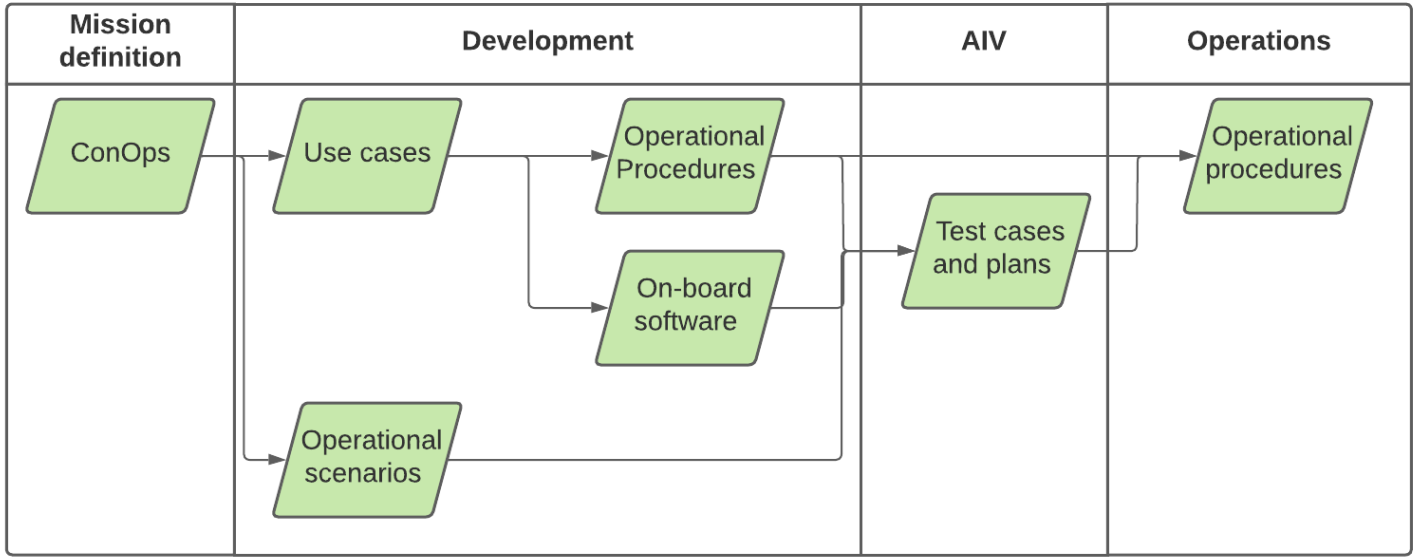
JUVENTAS: TEST-DRIVEN DEVELOPMENT APPROACH

- How cubesat teams can innovate

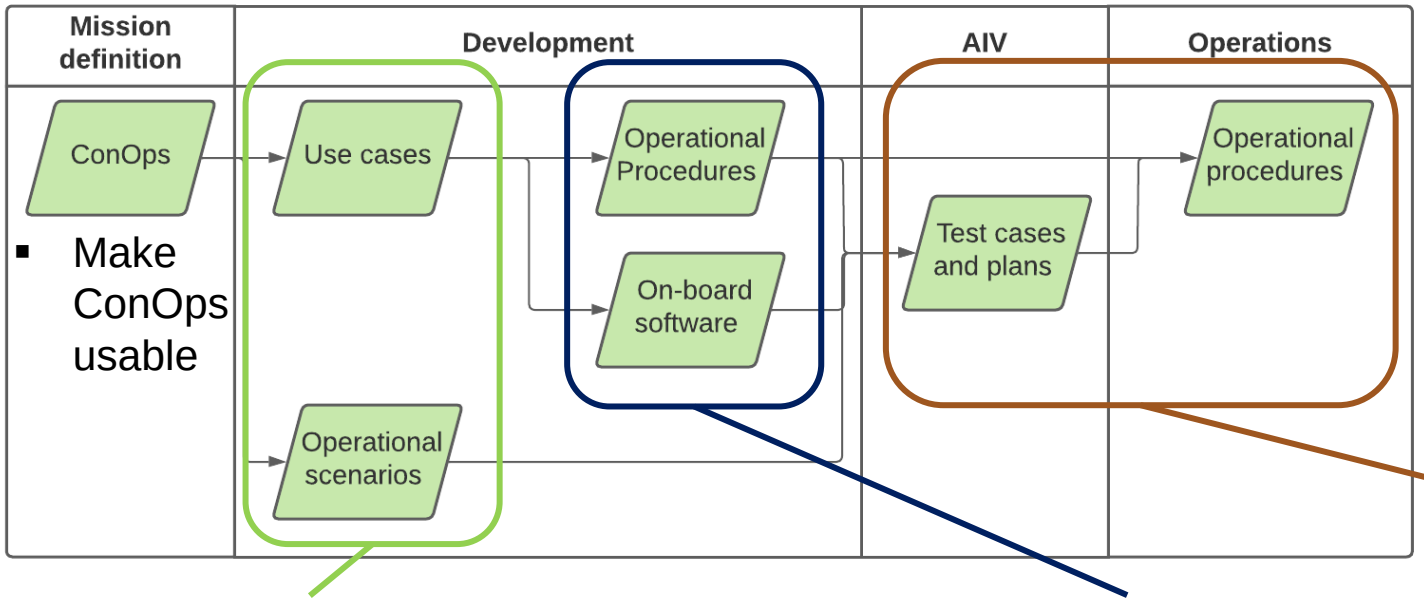
JUVENTAS: TEST-DRIVEN DEVELOPMENT APPROACH



- Juventas deep space mission as part of HERA
- High level of autonomy needed
- New ConOps for deep space wrt LEO missions



JUVENTAS: TEST-DRIVEN DEVELOPMENT APPROACH



- Make ConOps usable

And connect it all in an automated workflow

- Use cases and op. scenarios replace functional requirements
- Written by systems eng.
- Same use cases and op. scenarios are used for power, thermal, AOCS simulations

- On-board procedures as SW specifications
- Continuous integration environment
- On-board procedures as test cases for SW integration

- Same procedures used for SW tests, flatsat/ATB, flight models testing, and operations
- No separate tools for ops. development and validation

JUVENTAS: DETAILED WORKFLOW

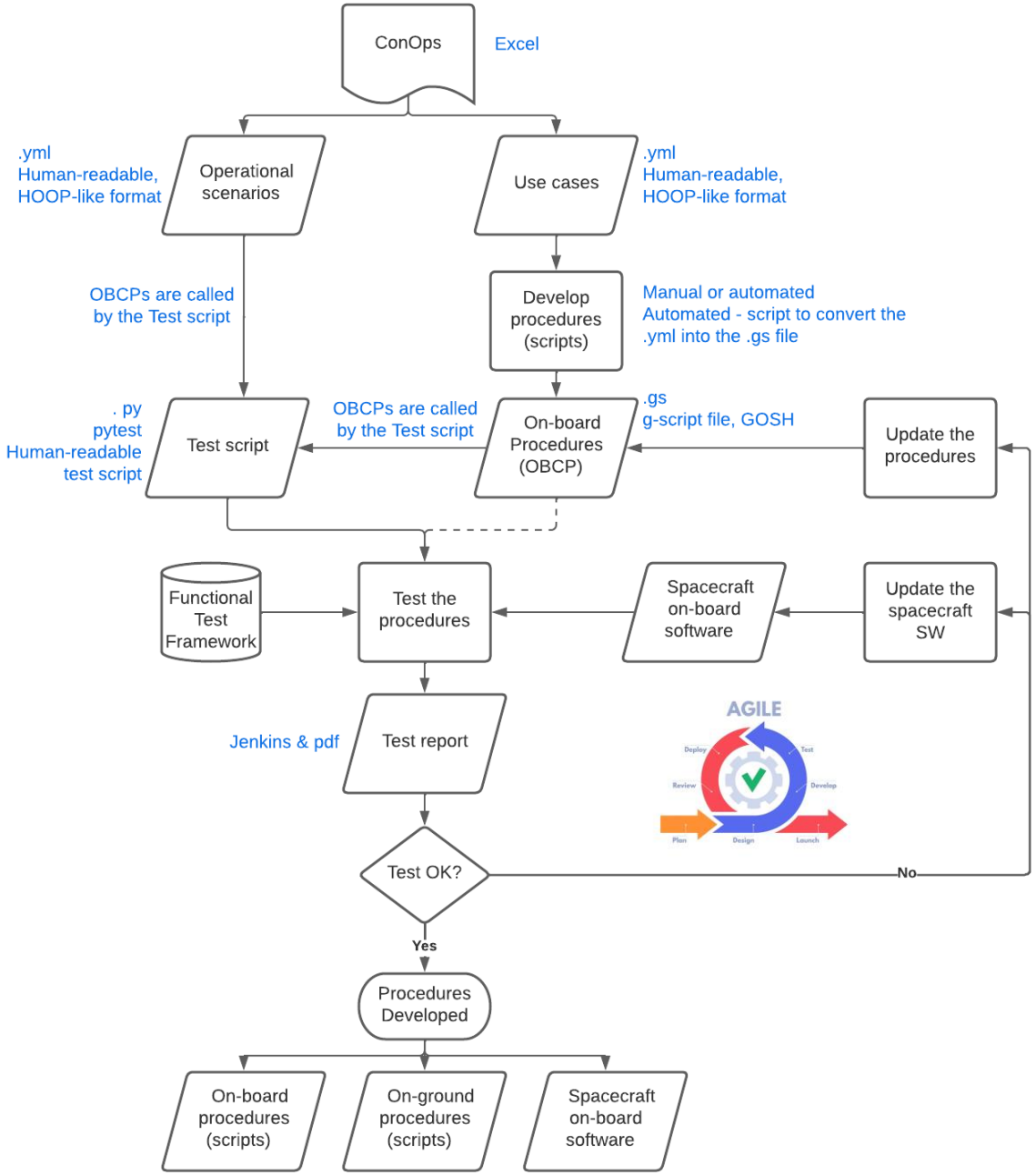
Workflow used for
- Development phase
- Operation phase (update or new procedures)

- First step – Human-readable pseudo-code
- Second step – Convert in list of commands

- Use Cases
- Operational Scenarios

} On Board Control Procedures (OBCPs)

- OBCPs ≠ Flight Operation Procedure involving ground



JUVENTAS: USE CASE EXAMPLE

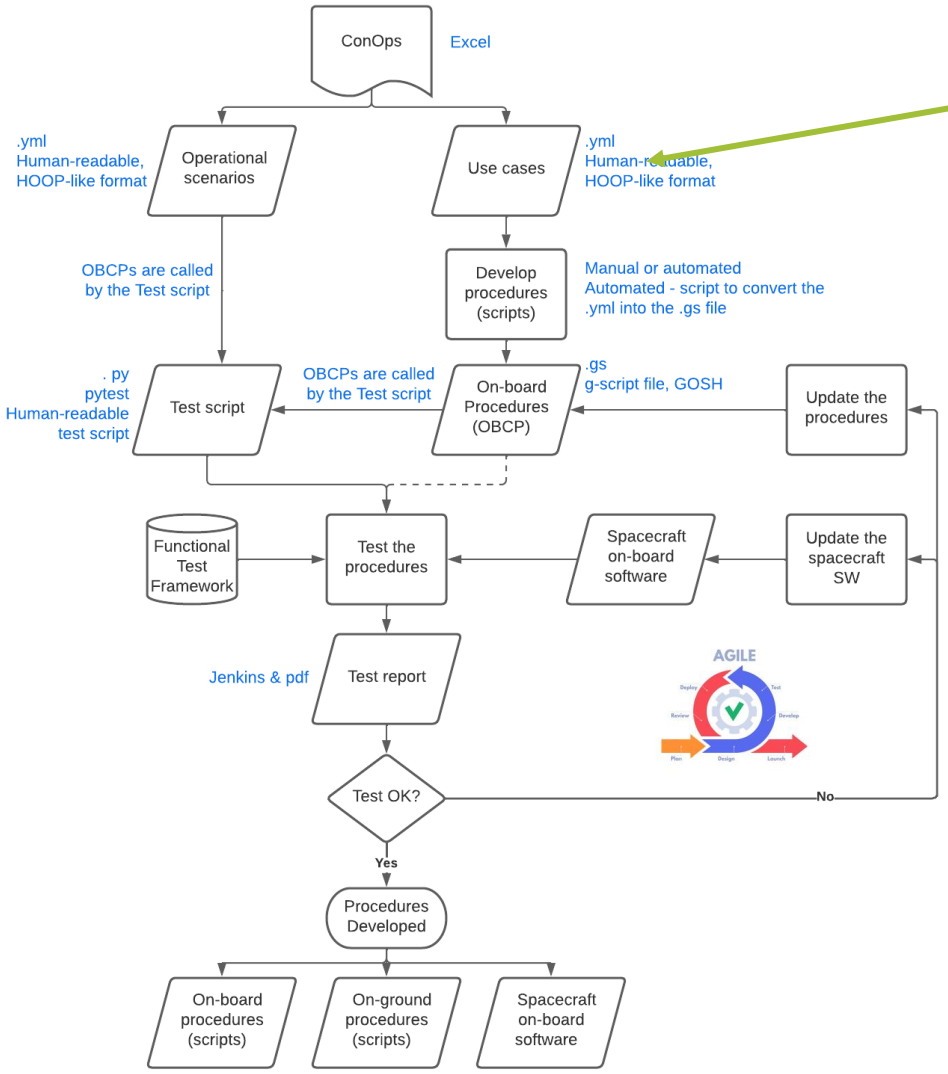
- Human readable yaml file
- Desired operation
- Commands – if known

Operation

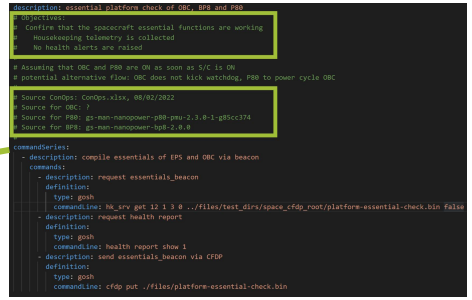
Commands

```yaml
description: essential platform check of OBC, BP8 and P80
# Objectives:
#  Confirm that the spacecraft essential functions are working
#    Housekeeping telemetry is collected
#    No health alerts are raised
#
# Assuming that OBC and P80 are ON as soon as S/C is ON
# potential alternative flow: OBC does not kick watchdog, P80 to power cycle OBC
#
# Source ConOps: ConOps.xlsx, 08/02/2022
# Source for OBC: ?
# Source for P80: gs-man-nanopower-p80-pmu-2.3.0-1-g85cc374
# Source for BP8: gs-man-nanopower-bp8-2.0.0
#
commandSeries:
  - description: compile essentials of EPS and OBC via beacon
    commands:
      - description: request essentials_beacon
        definition:
          type: gosh
          commandLine: hk_srv get 12 1 3 0 ../files/test_dirs/space_cfdp_root/platform-essential-check.bin false
      - description: request health report
        definition:
          type: gosh
          commandLine: health report show 1
      - description: send essentials_beacon via CFDP
        definition:
          type: gosh
          commandLine: cfdp put ./files/platform-essential-check.bin
```

JUVENTAS: WORKFLOW EXAMPLE



Use case



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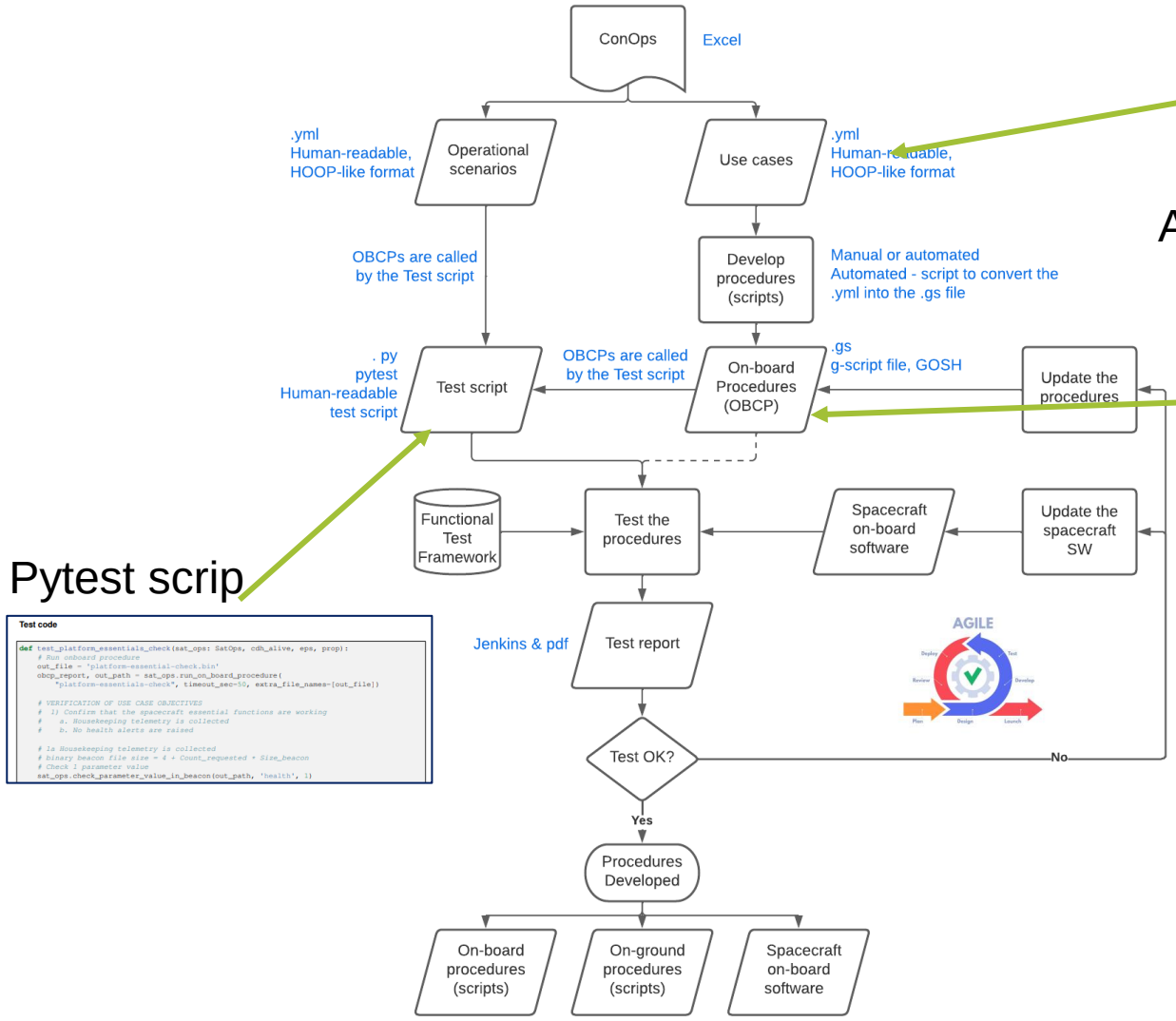

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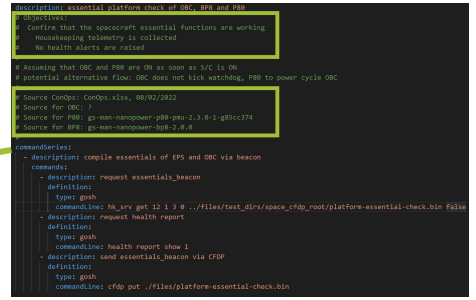


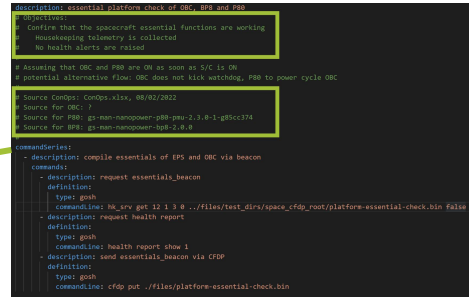
Autogenerated onboard (flight) procedure

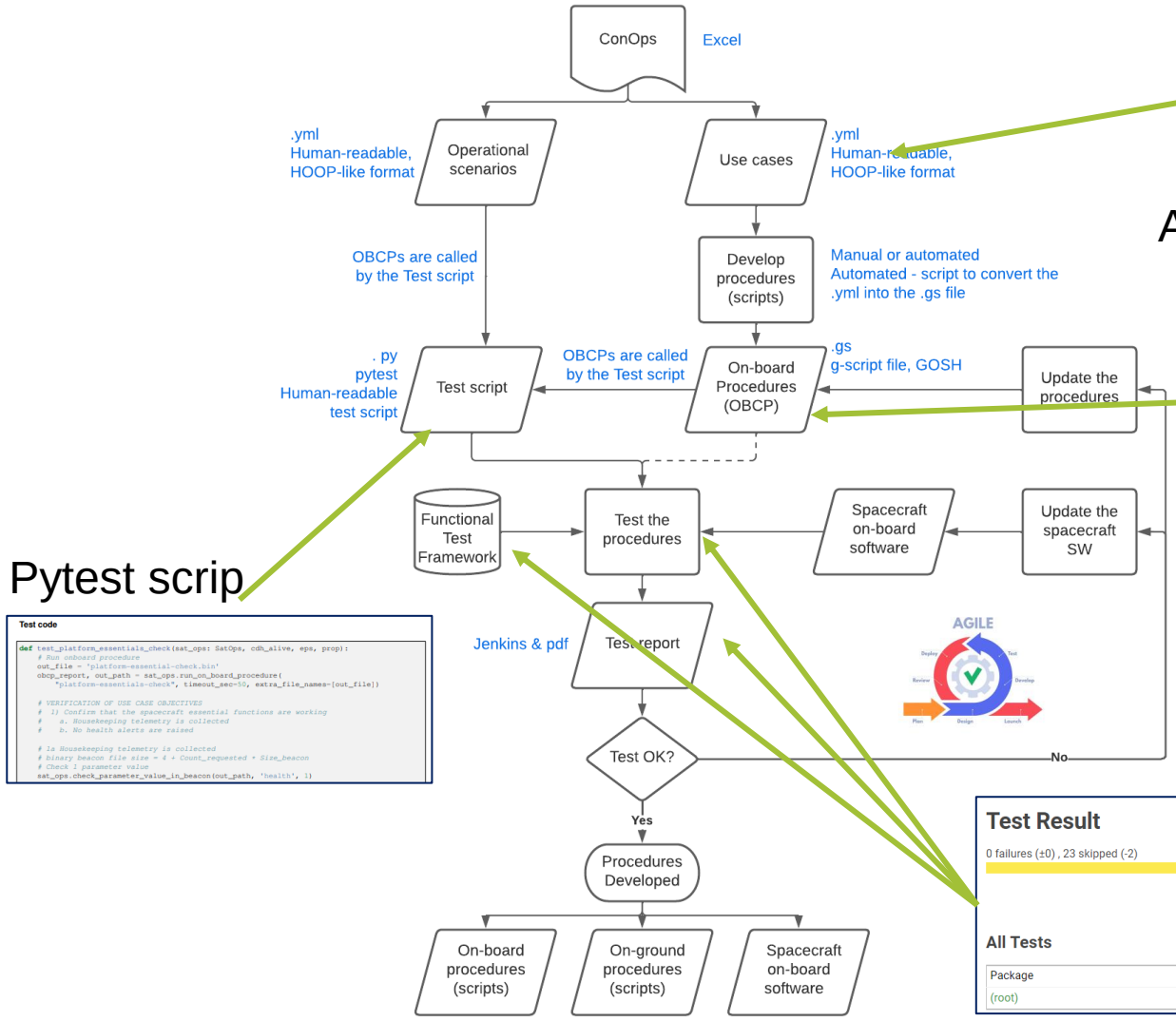
```
1  # Gscript syntax: <delay mS> <retry> <err_goto line> <cmd>
2  0 0 0 gsext log enable ./obcp.log 1
3  10000 0 0 hk_srv get 12 1 5 0 platform-essentials-check.bin false
4  10000 0 0 health report show 1
5  0 0 0 cfdp put platform-essentials-check.bin 1
6  0 0 0 gsext log disable
7  0 0 0 gsext log enable ./obcp_log_handling.log 1
```

Pytest scrip

JUVENTAS: WORKFLOW EXAMPLE

Use case





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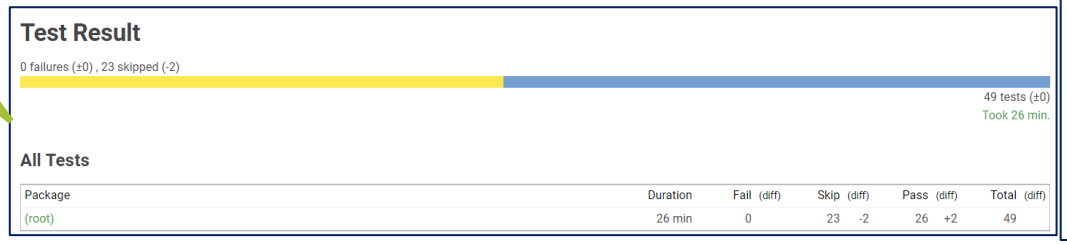
```

Pytest scrip

Jenkins continuous integration and automated reporting



JUVENTAS: TEST-DRIVEN DEVELOPMENT APPROACH

- Efficient and automated workflow
  - From system engineering use cases to SW functions and flight procedures
- Deployed and in active use
  - Juventas
    - Functional test framework (Sw development and validation)
    - Flatsat tests
    - Spacecraft model tests (EM)
    - …
  - Commercial mission
    - Flatsat tests
    - Mission operation system tests
    - …
  - CubeMap – deployment is starting
  - GOMX5 – deployment is starting

- Next steps
  - Deployment on flight models (Juventas PFM)
  - Merging with GOMSpace new mission operation environment (HOOP MCS, Grafana)

- Want to know more?

73rd International Astronautical Congress (IAC), Paris, France, 18-22 September 2022.

IAC-22-B4,8,x73905

JUVENTAS CUBESAT IN SUPPORT OF HERA MISSION TO DIDYMOS ASTEROID SYSTEM: TEST-DRIVEN IMPLEMENTATION

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"We help teams across the globe achieve their goals in space"

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BACKUP

JUVENTAS: CONOPS APPROACH

Mission phases

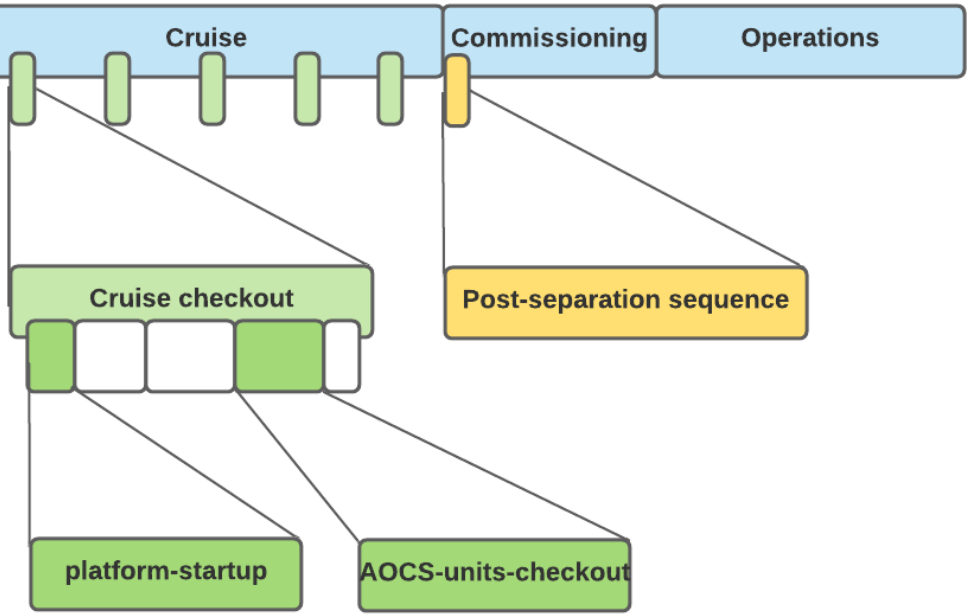
Implemented as Flight plans (.fp files) = Mission Time-Line (MTL);
Includes absolute timeline as needed for mission phases;
Will call the operational scenarios or use cases (.gs files)

Operational scenarios

Implemented as gscript (GOSH scrip; .gs files);
Will call the "use case" (.gs) files
Timed sequence of use cases

Use cases

Implemented as gscript (GOSH scrip; .gs files);
Timed sequence of GOSH commands



This approach improved engineering communication and consistency, and is now also adopted by other GOMSpace projects

Operational Scenario	Description and constraints	Scenario's purpose	**Use Case** or <<Event>>	Flight Orientation	Spacecraft Mode	Duration [s]
SSTO 3.3km Science Arc	A segment of an oribit (arc) with JuRa and Radio Science measurements	flight procedure; input to power budget - verification; input to Mission Operations Plan - duration and operations	platform-standby	Didymos-pointing	Nominal Mode	0
			JuRa-observation	Didymos-pointing	Nominal Mode	2700
			platform-standby	Didymos-pointing	Nominal Mode	300
			radio-science-measurement	Didymos-pointing	Nominal Mode	1500
			platform-standby	Didymos-pointing	Nominal Mode	0