The Virtual Spacecraft Reference Facility

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On-Board Software Systems Section
## Agenda

- **Why?**
- **What?**
- **How?**
- **When?**
The Virtual Spacecraft Reference Facility – architecture view
The Virtual Spacecraft Reference Facility – user view
The problem

- Many of the R&D activities on software tools or software components never reach the needed maturity level due to lack of validation in a representative Spacecraft Environment.

- Example: Company A develops a new method for dynamic analysis of on-board software. The study is on the method but it requires a “real on-board software” test case to prove its value. The “hello-world” test case is not sufficient nor convincing.

- Key requirement: “Validation in context”
Example: Mars Pathfinder

- **July 4th 1997**
- **Problem:** Random system resets
- **Cause:** Priority inversion

**Ref:**

- [www.cs.cmu.edu/afs/cs/user/raj/www/mars.html](http://www.cs.cmu.edu/afs/cs/user/raj/www/mars.html)
- [http://www-cs.cmu.edu/afs/cs/user/raj/www/mars.htm](http://www-cs.cmu.edu/afs/cs/user/raj/www/mars.htm)

Why does this happen?

1. Validation not performed in Context
2. Validation in a simplified environment or by similarity is simply not good enough
3. Models are an approximation
Where in the process does it go wrong?

Technology Readiness Levels - The missing links

1. Technology Concept and/or application formulated
2. Analytical and experimental critical function and/or characteristic proof-of-concept
3. Component and/or breadboard validation in laboratory environment
4. Component and/or breadboard validation in relevant environment
5. System/subsystem model or prototype demonstration in a relevant environment (ground or space)
6. System prototype demonstration in a space environment
7. Actual system completed and “Flight qualified” through test and demonstration (ground or space)
8. Actual system “Flight proven” through successful mission operations
Objective

- Develop a Virtual Spacecraft Reference Facility that provides a simulated spacecraft context suitable for demonstrating and validation of R&D results.
- The VF-RF shall be modular such that it is suitable for creating a software test bench with all simulated devices or an avionics test bench with hardware-in-the-loop.
- It shall be a moving target
Stake holders

Technology validation with the following cross domain undertakings:

• On-board Software
• Simulation Technologies
• Data Handling
• Avionics
• Software engineering and Standardization
• Ground Support Equipment
Potential Experiments

- Software Framework initiatives
- SOIS
- Bus protocol stacks (SpaceWire, 1553 …)
- Autonomy initiatives
- AOCS (algorithms, model, autocode …)
- Simulation Model interface standardisation effort
- Software development methods & tools
- Test tools (SCOS-2000, SDB, Pluto …)
- Mass Memory experiments
Starting point.

- Based on tailoring of already developed on-board software, environment simulation models, Software Validation Facility, etc. create a Virtual Spacecraft Reference Facility

- Elements (but not limited to)
  - OBOSS Packet Utilization Standard Library
  - AOCS framework
  - Eurosims
  - SVF
  - Visualization Software
  - SCOS-2000

- The VS-RF shall continuously be evolving to include new developments. (Moving Target)
**Virtual Spacecraft Reference Facility (VS-RF)**

- **Version 1:** All software implementation of the Virtual spacecraft;
  - Target: software validation (simulated real time).

- **Version 2:** Iron bird / avionics test bed
  - Target: Hardware In the Loop Communication bus implementations (e.g. 1553, SpW)
The VS-RF v1

- **Mission definition:**
  - Mission Requirement document (simple polar orbit)
  - Defined command and control services (G/S ICD)
  - Spacecraft Architecture

- **Implementation**
  - Data management software (running on RTEMS/ERC32).
  - AOCS software
  - Environment simulation (avionics devices, dynamics)
  - Environment simulation infrastructure
  - Software validation facility
  - COTS tools
Mission Requirement - The EagleEye Mission

- The mission drives the requirements.
- Characteristics:
  - 250 kg
  - Low Earth Orbit (Sunsynchronous, $\alpha=7050$km, $i=98.2^\circ$)
  - Payload: High Resolution Imaging Camera
  - Mass memory 80 Gbit
  - One ground station (Svalbard)
  - S-band link: 2 kbps up and 4 kbps down
  - X-band link: 100 Mbps.
Virtual Spacecraft Architecture
-The EagleEye Mission

- **Payload**: GoldenEye
- **Data Management System**: SSMM, CDMU
- **RF Communication**: X-band, S-band
- **Power subsystem**: Solar Array, Battery, PCDU
- **Thermal subsystem**: Temp. sensors, Heaters
- **AOCS subsystem**
  - **sensors**: GPS, Gyros, Sun Sensor, Star tracker, Magnetometer
  - **actuators**: Reaction Wheels, Thrusters, Magnetorquer

**Systems and Subsystems**:
- **Serial**
- **1553 RT**
- **Analog**
Virtual Spacecraft Reference Facility

VSRF User Interface 2/2
What makes the VS RF different from other testbenches?

- It is an infrastructure concept, not only a set of tool(s), it is a moving target.
- A Technology Validation process applied to it.
- Targeted for Technology Validation.
- Open System; OBSW, Models, SVF are open source with standardized interfaces (*1). Mostly non proprietary infrastructure elements.

*1) Under license agreement with ESA
Implementation - Workflow

- AOCS Control Law
  Sener (ES)

- OBSW and SVF
  Terma (DK)

- Integration and EuroSim models
  Dutch Space (NL)

- AOCS Simulation models
  ESA

- Status:
  Kicked off in Januari 2004.
  Finished end of this year
Organisation

- A small budget was available for tailoring contracts to get the thing going.
- Sustainable investment funding is requested for the coming years.
- Particular study configurations are not covered by the VS-RF budget, i.e. the experimenter (R&D contract) pays for his own experiment.
Summary

• The Virtual Spacecraft Reference Facility is an infrastructure to be used for demonstrating and validation of R&D results.
• Validation in context!
• It will continuously be developed (through industrial contracts) to satisfy requirements from the stakeholders domains:
  - On-board Software,
  - Simulation Technologies
  - Data Handling
  - Avionics
  - Software engineering and Standardization
  - Ground Support Equipment
The Virtual Spacecraft Reference Facility

Q&A

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