J³
CubeSats as a Platform for In-Orbit Verification of Scientific Instruments for Interplanetary Missions

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CubeSats as a Test Platform

• Development in the recent years:
  – Availability of COTS CubeSat components
  – Experience with CubeSat development & operations increases

• Result:
  – Entry barrier continues to being lowered
  – Rapid development of CubeSat missions become feasible
J³ Mission

• Goal:
  – Test of components for instruments for the JUICE mission to Jupiter

• Design requirements:
  – Formfactor: 1U CubeSat, ½U Payload
    • Limit launch costs
  – COTS Components
    • 3x-10x cost reduction compared to RAD-hard components
    • Reduce development time
    • Reduce design inherent risk
Development Workflow

Available COTS Subsystems → Configuration Generation

Configuration Generation → Component Characteristics

Component Characteristics → Experiment Requirements

Experiment Requirements → Possible Configurations

Possible Configurations → Mission Simulation

Mission Simulation → Configuration Trade-Off

Configuration Trade-Off → Science Score

Science Score → Requirement Satisfaction

Requirement Satisfaction → Mission Simulation

Mission Simulation → Requirement Satisfaction
Configuration Generation

- Search sets of components which fulfill payload requirements
- Match requirements and capabilities of selected components
- Output configurations which have no open requirements
Requirements/Capabilities
Visual Example

Legend:
- Capability ➔ Requirement

- 3.3V
- Data TX
- Data RX
- Vbat
- UHF-Antenna
- VHF-Antenna
- S-Band-Antenna
- NanoCom AX100
- NanoCom U482C
- UTRX
- C1U
- VUTRX
- TRXUV
- TRXVU
- TXS
- CS S-Band
- HISPICO
- ANT430
- 2M
- TSU
- SDU
- SDU+1M
- CDUV
- S-Patch HISPICO
- S-Patch Clyde
Examples for Different J³ Configurations

- EPS Type A
- OBDH Type A
- T&C Type A
- RATEX-J
- Antenna Type A
- Solar Panel Type A

- EPS Type B
- OBDH Type A
- T&C Type B
- RATEX-J
- Antenna Type B
- Solar Panel Type B
Mission Simulation

- Simulate complete mission for generated solutions
- Reduce complex trade-off criteria into scientific output score
- First verification of some design requirements

Component Characteristics
Possible Configurations
Mission Simulation
Science Score
Requirement Satisfaction
Mission Simulation

STK 10

Orbital Simulation

Sunlight Vector

Power Generation Calculation

Available Power

Activity Profile

Components

Power System Simulation

Controller

Transmitter On/Off

Payload On/Off

Simulate

MATLAB

Define

Battery State Instrument Run-time

Communication Run-time

Latitude

Longitude

Altitude
Mission Simulation

Science Score

- Score the spacecraft based on the science output generated
- Score based on the mission description
  - e.g. J³: Simulated amounts of electron counts
Mission Simulation

Energy Budget

- Simulate the performance of the electrical power system
  - Energy collection by solar panels
  - Battery charge controller efficiency
  - Power rail converter efficiency
    - Based on simulated load of the subsystems
- Verify depth-of-discharge limits can be obeyed
### Mission Simulation

#### Energy Budget

- **J³:**
  - Different converter load/efficiency curve have significant impact on available power

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![Graph showing energy budget over time](image-url)
Mission Simulation
Communication & Data Handling

• Simulate storage of generated data
  – Test if satellite does not run out of memory

• Simulate ground contact windows and link budget
  – Estimate bit error rates
Mission Simulation
Communication & Data Handling

- **J³:**
  - No need for a high speed data link (>9.6kbps) has been identified
    - Ground contact almost every orbit (>75%), at most after 5 orbits
      - Ground station based at high latitudes
    - Relatively low data generation
      - ~32 kByte/orbit
Trade-Off

• Trade-Off criteria have been reduced by determining the influence on the science output

• Few manual trade-off classifications remain:
  – e.g. development effort
    (software, customization of hardware)
Conclusion

- 1U CubeSat mission feasible for complex test article
- Tools for future missions have been developed to speed up the process further
- Future work:
  - More extensive component requirement/capability description to reduce manual filtering