ROS in Space

Thoughts on Developing and Deploying ROS for Space Robotics

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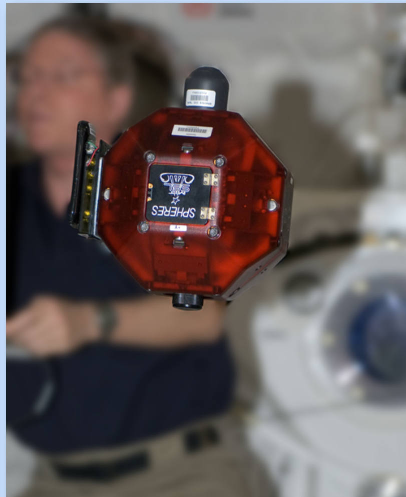
Space Robotics

PROTOTYPES



FLIGHT SYSTEMS

Prototypes

Custom use cases

- **Planetary rovers**: natural terrain, instruments, multiple modes
- **Free-flyers**: full 6-DOF in micro-gravity
- **Dexterous manipulators**: in-space and planetary surface operations

Diverse deployments

- Laboratory – indoor & outdoor
- Field tests – planetary analog sites (craters, deserts, etc.)
- International Space Station

Robot software requirements

- Support **applied** research & development
- Enable **complex** proof-of-concept / demonstrations
- Facilitate deployment (including constraints: comm, ops, etc.)

Flight Systems (1)

Design to minimize risk

- Risk (technical, schedule, mission) is due to complexity
- Complexity = how hard something is to understand or verify
- Good software **architecture** is the most important defense against incidental complexity

Fanatical emphasis on code quality (# defects/KLOC)

1.0 Software industry average

0.5 Open-source projects (2011 Coverity survey)

0.6 Linux 2.6 (7 MLOC)

0.1 NASA flight software (mission critical code)

Use of fault protection

- Fault containment (limit cascade effects)
- Randomized testing (avoid bias to specific errors)

Flight Systems (2)

Documentation

- Design & implementation details
- End-to-end traceability from requirements to code

Software V&V

- **Verification**: demonstrate that software meets requirements
- **Validation**: demonstrate that software satisfies its intended use in its intended environment

Lines of Code

Roomba	1 KLOC
Stanley	100 KLOC
Mars Exploration Rovers	555 KLOC
Curiosity rover	2,000 KLOC

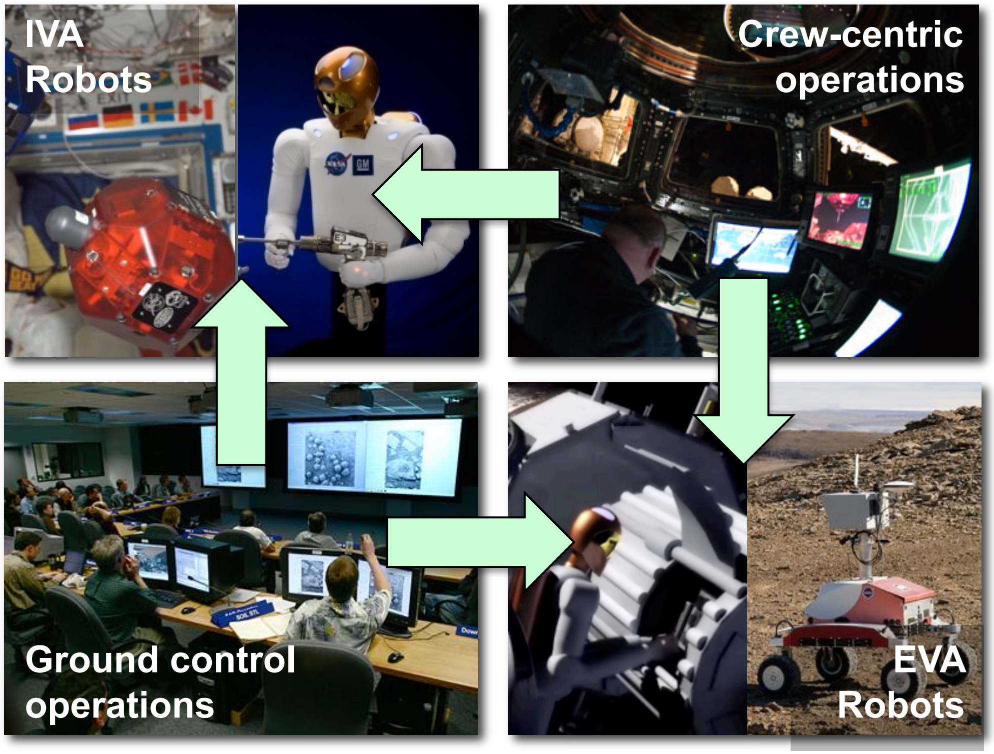
Control Modes for Space Robots

Ground control

- **Mission control** operates robot (on flight vehicle or other planet)
- Off-load routine & tedious work from astronauts: maintenance, repetitive tasks (e.g., inventory)
- Perform robotic exploration (e.g., field geology)

Crew centric

- **Astronauts** remotely operate robots from inside flight vehicle
- Extra-vehicular activities (outside vehicle, surface, etc.)
- Perform structural inspection, mobile sensor, surface field work



Robot Software Needs (1)

Framework

- Application structure
- Concurrency & synchronization
- Service management

Middleware

- Efficient data distribution (optimize transport & message size)
- Diverse data types, communication patterns, rates, QoS, latency
- Pluggable transport layer (if possible…)

Building blocks

- Robot skills and primitivies
- Services or behaviors or modules
- Structured data (e.g., maps)

Robot Software Needs (2)

Architecture

- Control loops
- Data flow patterns
- Layers

Support tools

- Simulation (for development & debugging)
- Data logging & replay
- Configuration management (versioning, dependencies, etc)

Use of ROS (by NASA)

Suitability

- ✔ Prototype work (including Space Station testing)
- ✘ Flight systems

Sustainability

- Will ROS exist **throughout** a project's lifecycle?
- Code stability & standards (API vs. ABI)

Code quality

- Design & implementation
- Correctness, robustness, reliability, defects

Licensing

- How can we guarantee that code really is unencumbered?
- Re-release / bundling

Tech support

- Bug fixes, documentation, design reference, etc.