Maintenance Issues for Very Long-Lived Robotic Space Systems

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Outline

- What Are Ultra Long Life (ULL) Systems?
- ULL Enabling Technologies
- Maintenance Challenges
- References

What Are Ultra Long Life Systems?

- Next step in robotic space exploration
  - Initial exploration of Solar System nearly complete
  - Next logical steps
    - Kuiper belt
    - Oort cloud
    - "Nearby" planetary systems
- Anticipated mission duration 50+ years

See [1] for more details

What Are Ultra Long Life Systems (cont'd)?

- **ULL Mission Classes (from [1])**

ULL Class	Description	Application
Class A	**Constrained in both fuel and power**	**Interstellar missions**
Class B	Constrained fuel, ample power	Relay spacecraft for outer planet spacecraft, Asteroid or comet hopper
Class C	Constrained in power, small fuel requirements	Robot colony on permanent dark side of planets and satellites
Class D	Ample power, small fuel requirements	Robot colony on planets and satellites where sun light is plentiful

ULL Enabling Technologies

- Avionics System
  - Polymorphic architecture with generic logic blocks
  - Self-repair/self-healing techniques
- On-Board Autonomy
  - Goal-oriented software, autonomous planning and execution
  - Autonomous fault-handling
  - Self-learning/self-discovery

Maintenance Challenges

- Determining/Controlling Spacecraft State
  - Sources of Uncertainty
    - Evolvable Hardware
      - Architecture changes over time
      - What remains constant?
    - Autonomous/self-learning software
      - Incompatibility between on-board, transmitted goals
    - Signal Delays
    - Low Data Rates
  - Resolving Uncertainty
    - Brute force
    - Accurate predictive state models (how?)
      - What are the invariants?
      - What's the appropriate level of abstraction?

Maintenance Challenges (cont'd)

- Autonomous/Self-Learning Software
  - Upgrade validation
    - On ground
    - On board spacecraft

Maintenance Challenges (cont'd)

- Mission Duration
  - Obsolete Technology
    - Flight System
    - Ground Support System
  - Long-Term Information Retention
    - Immediately applicable information
    - Context
    - See [2] for more examples
  - "Intervals of Societal Fatigue"

References and Further Reading

[1] S. Chao, J. Blosiu, "Ultra Long Life System Concept (Draft)", JPL Internal Report, November 6, 2000

[2] G. Benford, Deep Time, 1999, Avon Books, ISBN 0-380-97537-8

References and Further Reading

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[1] S. Chao, J. Blosiu, "Ultra Long Life System Concept (Draft)", JPL Internal Report, November 6, 2000

[2] G. Benford, Deep Time, 1999, Avon Books, ISBN 0-380-97537-8