The Need for a Paradigm Shift in Space Robotics Dependability

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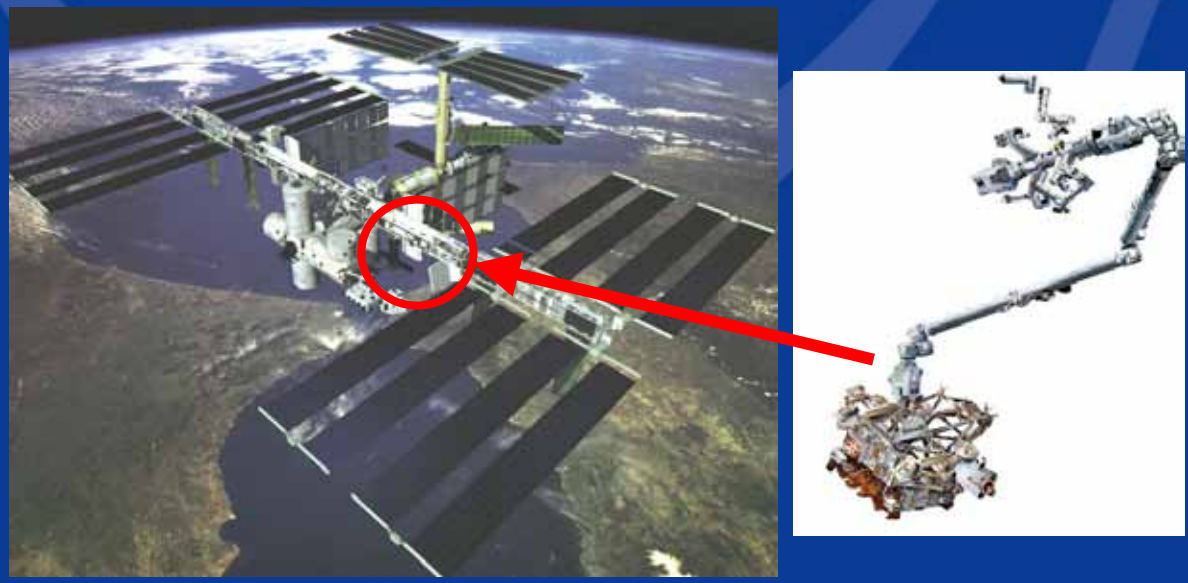
Definitions

- Dependability
  - Ability to Complete Mission…
  - … in a Safe Manner
- This is a discussion paper to get inputs from WS participants

Introduction

- Robots are everywhere in Space
  - ISS Construction Impossible without Canadarm 2



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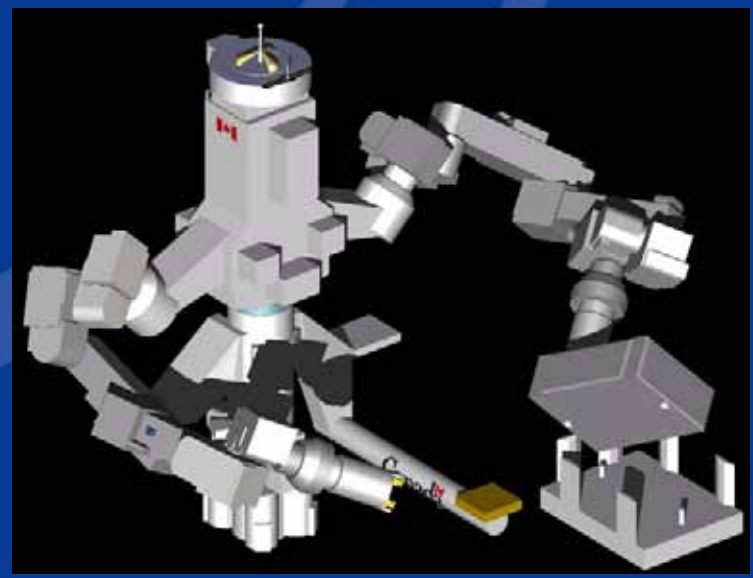
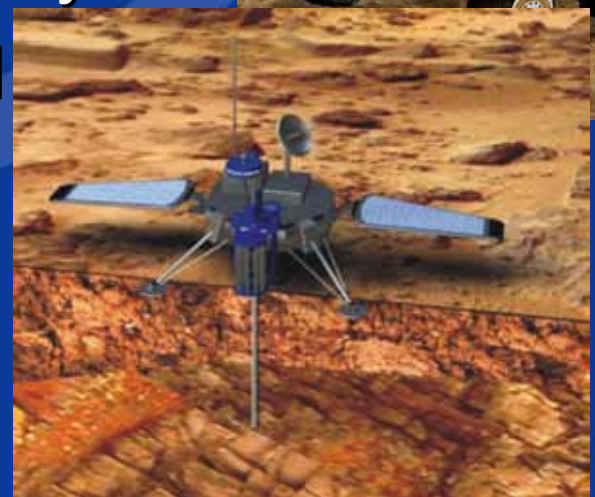


Introduction

- Robots are everywhere in Space
  - ISS Construction Impossible without Canadarm 2
  - Dextre essential to ISS Maintenance
  - Spirit & Opportunity have enabled breakthroughs in Mars Science

Introduction

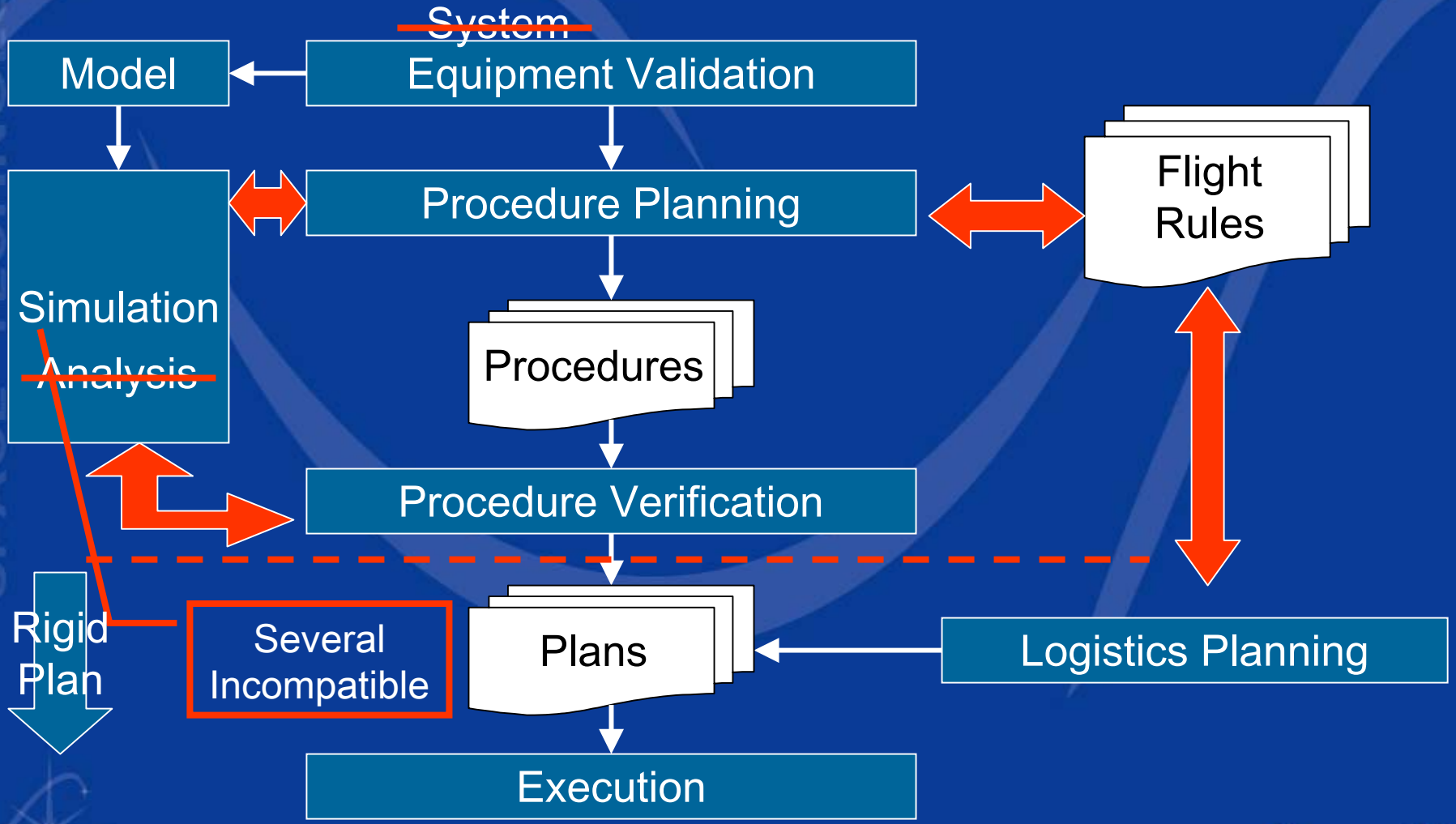
- Robots will be even more present in Future
  - Orbital Express
  - TECSAS
  - Mars Science Laboratory
  - New NASA Vision and Aurora Program



What is Specific to Space?

- Consequences of Failure
- Manned Missions
  - Crew Survival Critical
- High Missions Cost
  - Cannot Afford Losing Spacecraft
  - Success Expected on First Attempt
- Assets Not Easily Accessible for Repair

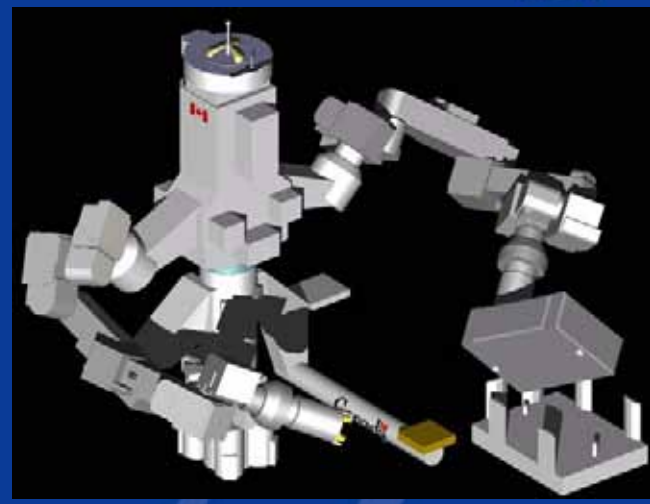
Dependability & Autonomy



Canadarm2

- Human-in-the-Loop Operations
- One-of-a-kind operations
- Structured/Known environment
- Deterministic Prediction Through Hundreds of Simulations
- 18 months start-to-finish
- Hundreds of Engineers Involved

What about Dextre?



- Recurring Operations
- High Volume of Operations
- Higher Complexity/Longer Timelines
- Some maintenance operations cannot be planned 18 months in advance
- Yet proposed approach for testing is similar… Pre-testing of several scenarios before execution

And Mars Missions?

- Environment is not structured
- Time delays: 10-40 minutes
- Communication windows (1 hour every 12 hours)
  - Operator cannot intervene
- Planning & Verification Process cannot be same
  - Limited Autonomy, Determinist Planning & Simulation
  - Model environment, plan operations, run simulations, all in 12 hours !!!
- Impact on productivity (e.g. 3 cycles to touch a rock)

What about future missions?

- TECSAS
  - Will Require Capture of a Moving Object
- Mars Science Laboratory
  - Talks of Driving "Over-the-Horizon" in a Single Command Cycle.
- Environment May Change Faster than Information is Fed Back
- Autonomy **WILL** be required

ARGO Framework

- ARGO: Autonomous Robotics and Ground Operations
- Objectives
  - Reduce Operations Costs & Increase safety:
    - Increasing On-board Autonomy
    - Integrating Operations Process: Planning, Verification, Execution, Post-Mission Analysis
- Philosophy
  - Full Spectrum from human-in-the-loop operations to semi-autonomous operations
  - Not an architecture: Set of Toolboxes

ARGO Framework

- History: Arose from Need for Ground Control
- Tooboxes
  - Cortex Autonomy Toolbox
  - Reconfigurable Ground Control Station
  - REMOTE Toolbox
- Hook in with Simulation Environment
  - E.g. MuT/Symofros

ARGO Sample Cases

- ARGO Bits and Pieces Applied in Several R&D Projects
- Have shown use of autonomy
- Not addressed Dependability Yet

Impact of Autonomy

- Decisions are event-driven
  - Sensor Data
  - Anomalies
  - Environment
  - NOT 100% PREDICTABLE
- Cannot predict deterministically
- Incompatible with current philosophy

Impact of No Autonomy

- Some Tasks Cannot be Performed
- Decreased Productivity
- Increased Cost of Operations

- Cannot Afford not to have it!
- **DEADLOCK!!!**

Consequences of Failure

- Manned Missions
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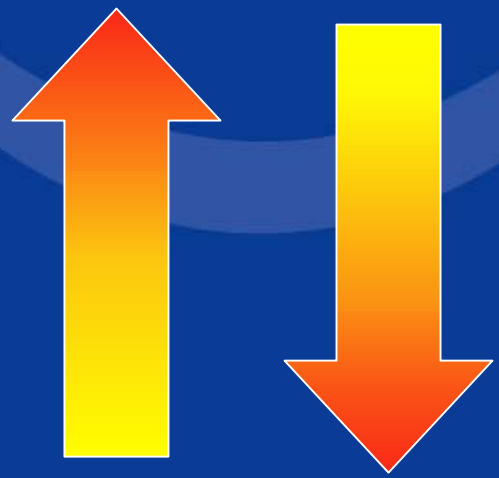
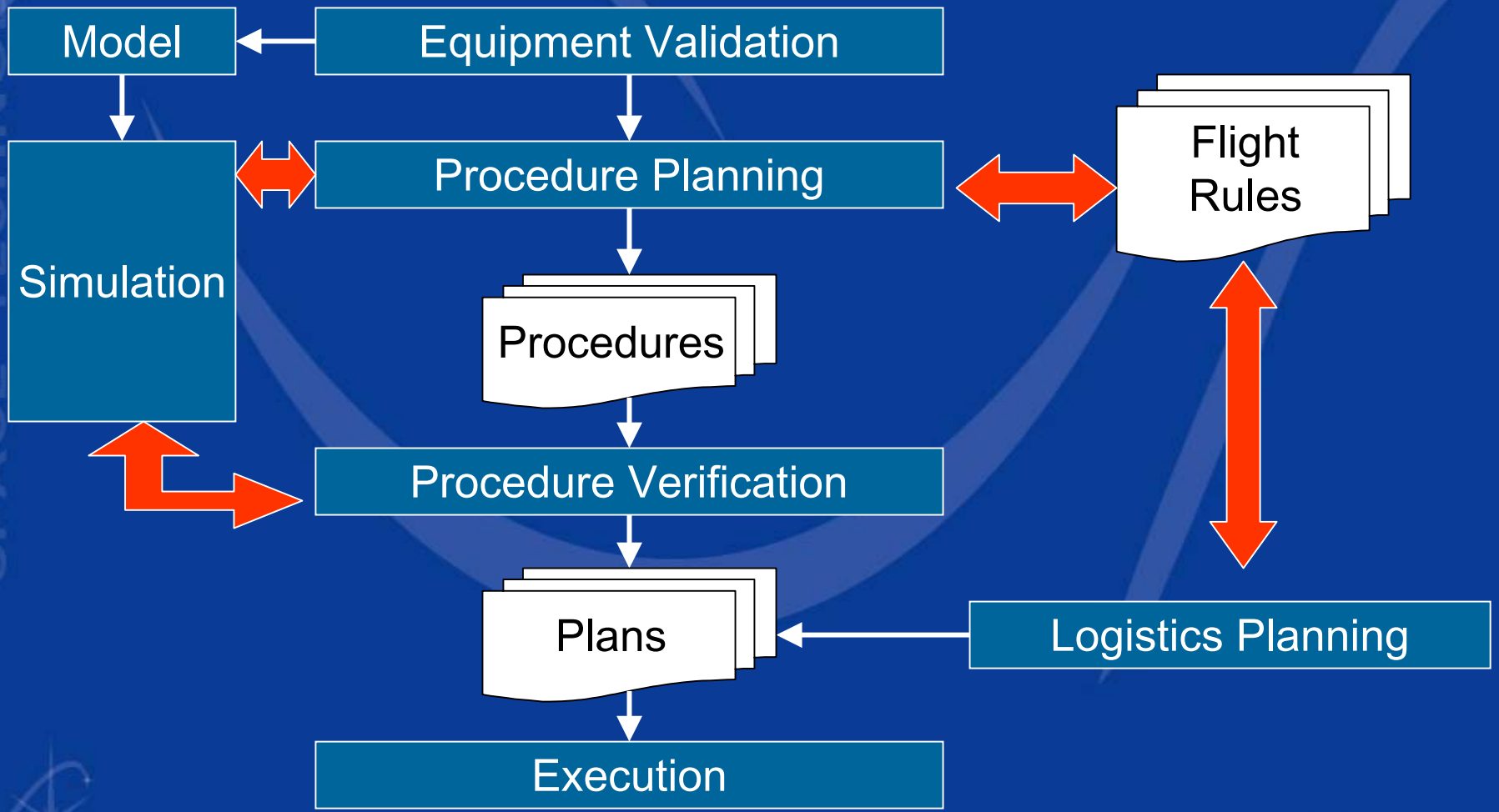
Hint of Solution

- Must Guarantee Safety
- Cannot Guarantee Successful Completion of Mission on 1st Attempt
- Trade-Off Productivity and Predictability



Dependability & Autonomy



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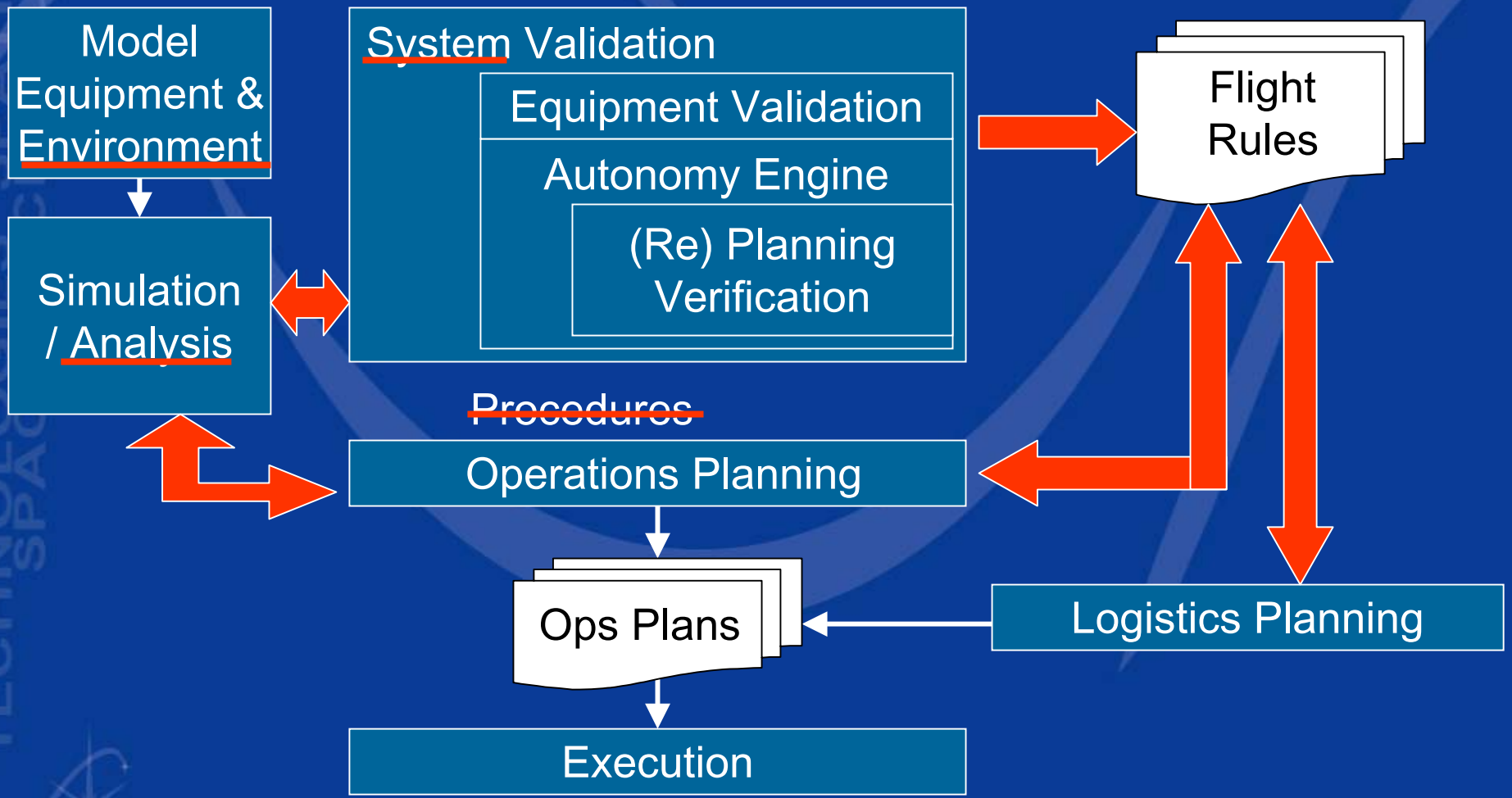

Conclusion

- Robots will be Omnipresent in Space
- Dependability is Crucial
- Autonomy will be Required (and has been demonstrated)
- Current Philosophy Based on Intensive Deterministic Simulation
- Autonomy Incompatible with Current Philosophy

Answers?