Contingency Software in Autonomous Systems

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PROBLEM STATEMENT

Autonomous vehicles currently have a limited capacity to diagnose and mitigate failures.
We need to be able to handle a broader range of contingencies (anomalous situations).

GOALS

1. Speed up diagnosis and mitigation of anomalous situations.
2. Automatically handle contingencies, not just failures.
3. Enable projects to select a degree of autonomy consistent with their needs and to incrementally introduce more autonomy.
4. Augment on-board fault protection with verified contingency scripts
1. **Identify contingencies** that risk mission-critical functions in a power system testbed (using S-FTA, S-FMECA, Obstacle Analysis)

2. **Model contingencies & autonomous recovery actions** using TEAMS (Testability And Engineering Maintenance System, QSI)

3. **Analyze contingencies**: TEAMS produces diagnostic tree of checks needed to detect & isolate contingency, identifies missing checks and recovery actions

4. **Code contingencies’ diagnosis & recovery behavior** in the project’s planner scripting language (auto-translation from TEAM’s XML output)

5. **Verify contingency scripts** with hardware-in-loop simulation

Using the above steps,
- Verify contingency plans used by NASA projects
- Investigate issues in coverage of contingencies
- Test results on power system testbed
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Approach

1. TEAMS Model

- testRightCameraNotTooDark
  - Test: testRightCameraNotTooDark
  - Yes

- testLeftCameraNotTooDark
  - Test: testLeftCameraNotTooDark
  - Yes

2. Diagnostic Tree auto-generated

- Open Right Lens Cap
- Desaturate Right Camera

3. XML auto-translated to verify contingency handling on platform

   testRightCameraNotTooDark
   - Yes
   - No
   - Test: testRightCameraNotTooBright
   - No
   - Open Right Lens Cap
   - Desaturate Right Camera

 LABEL />
• Improved contingency handling needed to safely relinquish control of unpiloted vehicles to autonomous controllers
• More autonomous contingency handling needed to support extended mission operations
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Accomplishments

• Completed Autonomous Rotorcraft Project case study
  – Documented process & results (1 published & 2 submitted papers)
  – Performed hardware-in-loop testing of diagnostic tree
  – Project applied results, modifying camera controller to enable autonomous switching between color and video cameras

• Modeled MER Critical Pointing software to be reused on MSL
  – Called if commandability lost; before trajectory-correction maneuvers
  – Auto-generated diagnostic tree from TEAMS model of what is known when a “quit-failed” signal occurs
  – Supplemented available documentation

• New case study
  – ADAPT emulates a typical spacecraft power system with redundant power buses, a solar panel, and battery storage
  – The approach for developing contingencies resulted in critical function identification and preliminary identification of required contingency plans

• Described work at Mini-SAS at JPL
1. Contingency management of complex systems is essential to the robust operation of complex systems such as spacecraft, Unpiloted Aerial Vehicles (UAVs) and vehicles for Exploration missions.

2. Automatic contingency handling allows a faster response to unsafe scenarios, with reduced human intervention.

3. Results, applied to the Advanced Diagnostics and Prognostics Testbed, the Autonomous Rotorcraft Project UAV, and Mars Science Lab, pave the way to more resilient, adaptive autonomous systems.
Investigate and model with TEAMS key contingencies involved in safe software reconfiguration of power distribution systems to support autonomous operations

Demonstrate and verify a subset of the contingency responses we have developed on available platforms

Document process to encourage transfer to other NASA projects