Formation Algorithms and Simulation Testbed

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Motivation for FAST

- Some TPF concerns regarding Formation Flying (FF):
  - System Functionality
    - formation deployment and initialization
    - collision avoidance (in the presence of faults)
    - fuel balancing
    - complexity of end-to-end operation
  - Coarse Formation Control
    - collision avoidance
    - sun avoidance
    - target acquisition
  - Fine Formation Control
    - station-keeping
    - on-the-fly observation
    - instrument interactions
    - synchronized thruster firing
- These issues, among others, can be addressed by simulation.
The FAST Approach

- **Our approach:**
  
  Consider existing formation flying algorithm designs:
  - NASA Code R Distributed Spacecraft Technology
  - StarLight Project Phase A development
  
  Leverage above to jumpstart design of formation flying algorithms for TPF.
  
  Implement in a flight-like distributed real-time simulation environment:
  - NASA Code R Distributed Spacecraft Technology
  - Apply scenarios to shake out the system.

- **Result**
  
  We are developing a simulation testbed to demonstrate the end-to-end operation of multiple spacecraft formation flying in a distributed real-time environment.
Features of the FAST

- Advanced algorithms for formation flying
  - Formation Guidance (with collision avoidance)
  - Formation Estimation
  - Formation Control
- Relative sensor suite models (acquisition, medium, fine sensors)
- Distributed real-time execution on multiple flight-like processors
- Distributed real-time simulation on Beowulf cluster
- Inter-spacecraft communication model
  [latency, throughput, connectivity]
- Inter-spacecraft time synchronization
- Fault injection
  - spacecraft computer reset
  - thruster misfire
  - sensor failure
  - inter-spacecraft communication dropouts
- Functional interferometer model
  [demonstrates capability for formation flying to interferometer hand-off]
FAST Plan

- Demonstration of distributed real-time simulation environment
  2003: StarLight design running on distributed real-time system
  - Formation initialization
  - Stop-and-stare
  - Re-targeting

- TPF formation flying nominal operations
  2004: TPF nominal op's on desktop workstation
  - Formation synchronization
  - Observation on-the-fly
  - Basic collision avoidance
  2005: TPF nominal op's in distributed real-time (DRT)
  - Above TPF design executing on distributed real-time testbed

- TPF formation flying off-nominal operations
  2005: TPF off-nominal op's on workstation
  - Robust collision avoidance (e.g., S/C reset while in re-targeting maneuver)
  2006: TPF off-nominal op's on DRT system
  - Above in distributed real-time, with fault protection software

- TPF formation flying operation with interferometer
  2006: TPF operation with hand-off to interferometer on DRT system
  - Formation flying with demonstration of hand-off to interferometer
FAST in its Current Form

- Formation Attitude Control Algorithms (FACS) run with Software Executive on flight-like PowerPC CPUs running VxWorks.

- Environment simulation runs on a "cluster computer" with Intel Pentium processors running a real-time Linux.

- Console for commanding and data analysis on desktop workstation.
FAST Hardware Block Diagram

- Flight-like algorithms and software executing on flight-like processors. 
  VxWorks real time operating system on PowerPC processors
- Scalable multi-spacecraft simulation executing on cluster computer. 
  Linux with Real-Time Application Interface module on x86 processors.

Flight Algorithms and Software

Environment Simulation

Terrestrial Planet Finder Mission

Origins Mission

A NASA

Origins Mission

Flight Algorithms and Software

RTAI-Linux / x86

dynamics simulation

RTAI-Linux / x86

dynamics simulation

RTAI-Linux / x86

dynamics simulation

Sun Workstation

Cluster Head Node

Ground System Console
Summary

- TPF has funded the Formation Algorithms and Simulation Testbed to address concerns with the development of formation flying for flight.
- The FAST is pushing FF technology readiness toward flight: formation flying algorithms will be executing in a flight-like software executive, on flight like processors with flight-like environment.
- The FAST will help prove that formation flying will work for TPF:
  - performance of formation flying is achievable
  - robustness of formation flying is achievable