Terrestrial Planet Finder Mission

TPF

A NASA Origins Mission

Formation Algorithms and Simulation Testbed

Matt Wette, Dan Scharf, Eli McMahon, Ed Benowitz

Jet Propulsion Laboratory

4800 Oak Grove Dr.

Pasadena, CA 91109

2003 TPF Expo

Oct 14-16, 2003

Pasadena, CA

[version 1.05]

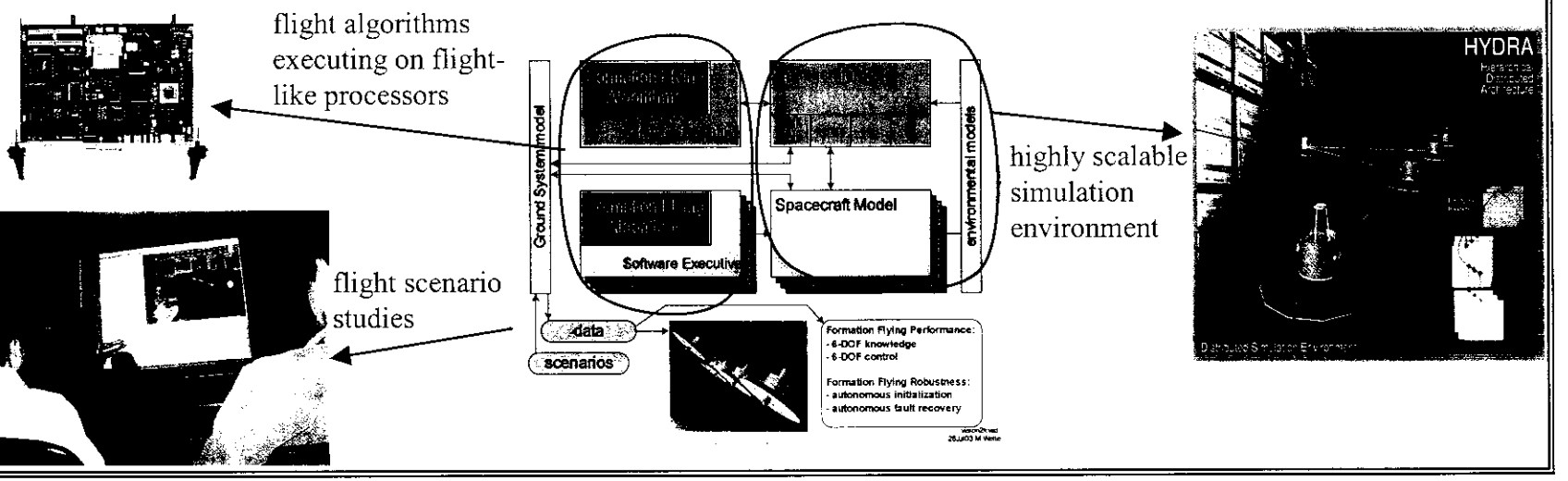
Motivation for FAST

- 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.



A NASA Origins Mission

Features of the FAST

- Advanced algorithms for formation flying
  - Formation Guidance (with collision avoidance)
  - Formation Estimation
  - Formation Control
- Relative sensor suite models (acqusition, 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]

TPF Terrestrial Planet Finder Mission

A NASA Origins Mission

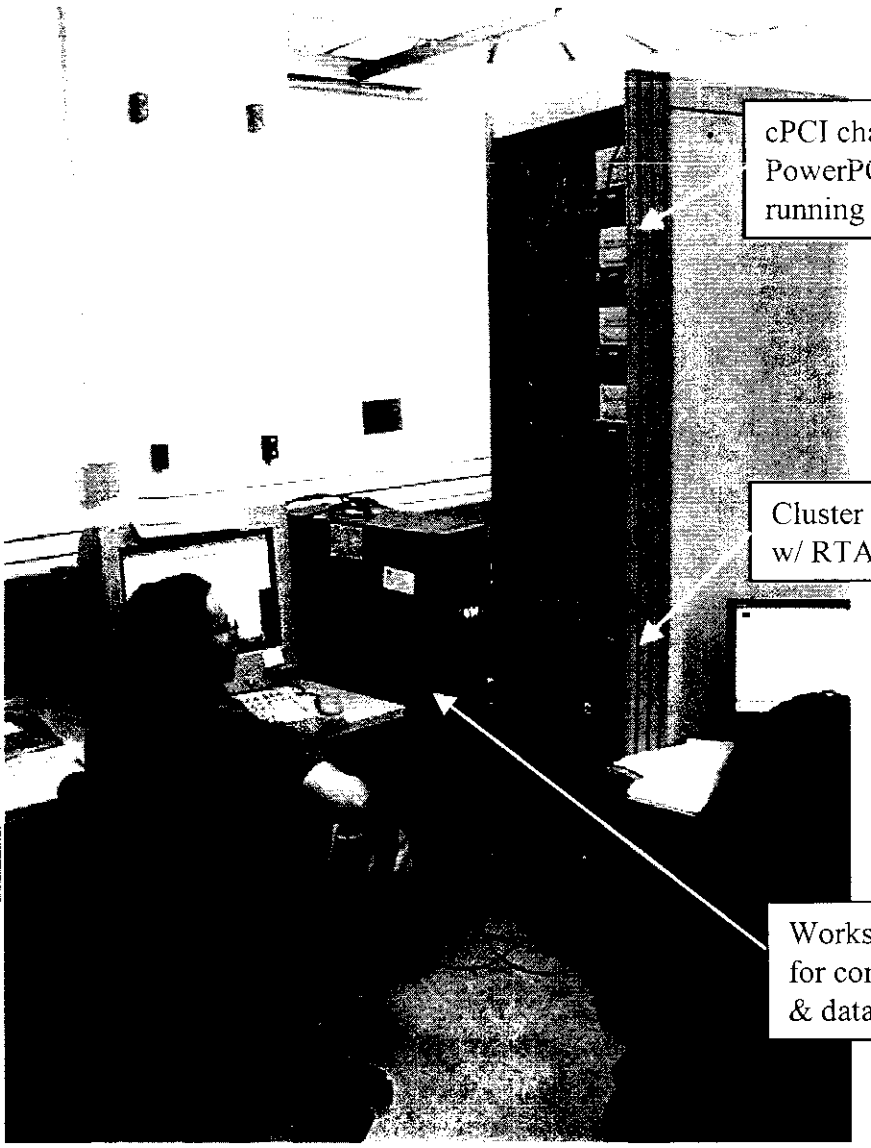
FAST Plan

- 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 retargeting 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

Terrestrial Planet Finder Mission

A NASA Origins Mission

FAST in it's Current Form

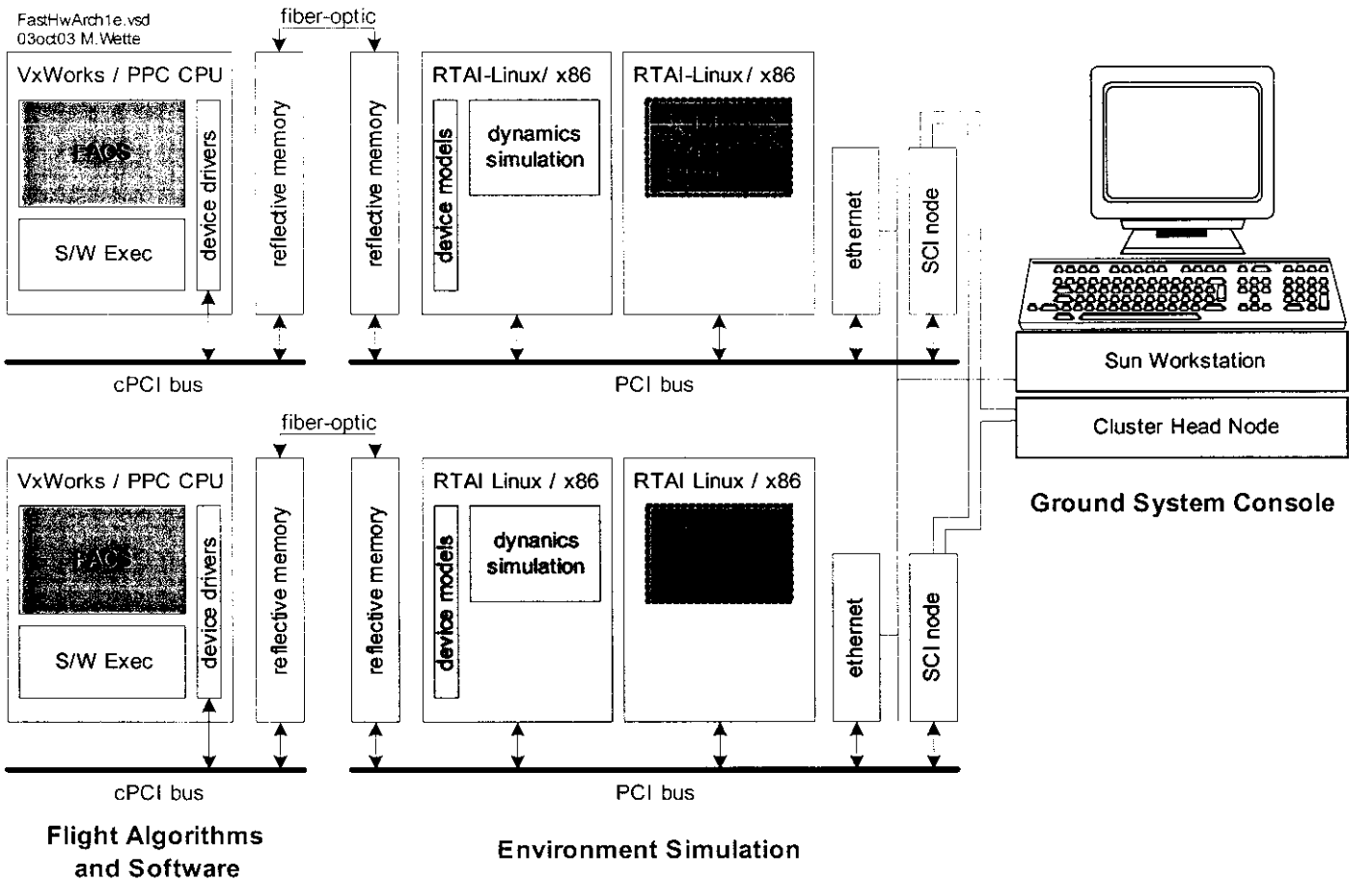


- Formation Attitude Control Algorithms (FACS) run with Software Executive on flight-like PowerPC CPUs running VxWorks.
- Environment simulation runs on a "cluster computer" with Intel Pentium processors running a real-time Linux.
- Console for commanding and data analysis on desktop workstation.

TPF Terrestrial Planet Finder Mission
A NASA Origins Mission

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.



Terrestrial Planet Finder Mission

TPF

A NASA Origins Mission

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

Terrestrial Planet Finder Mission

TPF

A NASA
Origins
Mission