TPF Formation Acquisition Sensor Testbed

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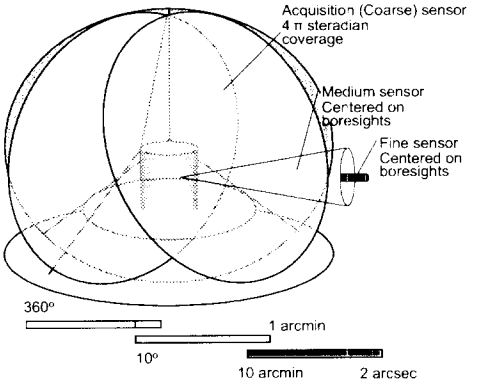
Purpose of the FST Acquisition Sensor Testbeds

To demonstrate feasibility of an acquisition (coarse) sensor

- Capability to determine relative positions (range & bearing angles) of all spacecraft initially within reasonable acquisition time.

Additional Goal: To minimize the acquisition sensor performance dependence on the s/c configuration



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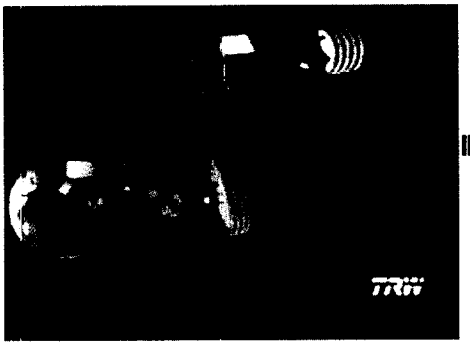

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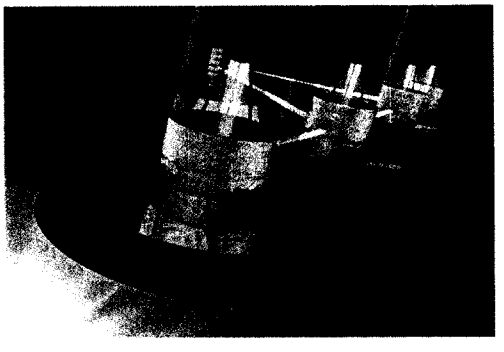
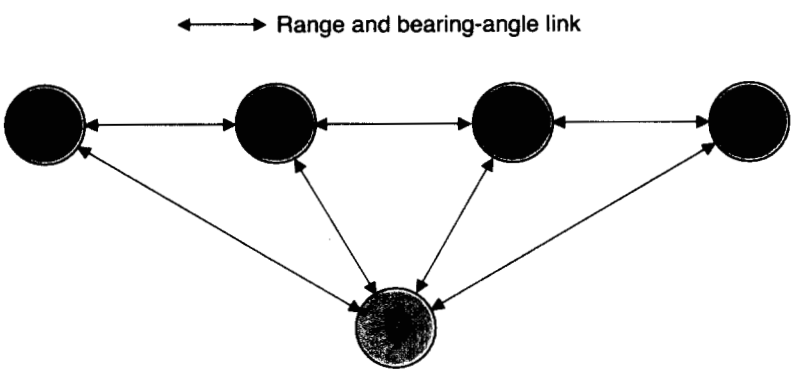


Assumptions for Relative-Sensor Requirements

- 5 spacecraft: 4 collectors, 1 combiner.
- Coarse sensor must be able to acquire from scratch: no a priori information about locations or orientations of other spacecraft.
- Each spacecraft must be able to determine the range and bearing of any other visible spacecraft.
- Coarse sensor must be able to acquire spacecraft while tracking others.
- Coarse sensor must be able to calibrate bearing angles by itself without maneuvering the spacecraft.
- The coarse sensor must maintain the integrity of the array indefinitely if power to the relative sensors is interrupted on one spacecraft ("radar mode")

Sensing Architecture of Acquisition Sensor



- Each spacecraft can sense every other spacecraft, subject to geometric blockage.
- Design is not dependent on a specific geometry of the array; 3-dimensional arrangement is OK.
- Both indoor and outdoor testbeds will implement 3 mocked-up spacecraft

TPF Formation Sensor Testbed Requirements

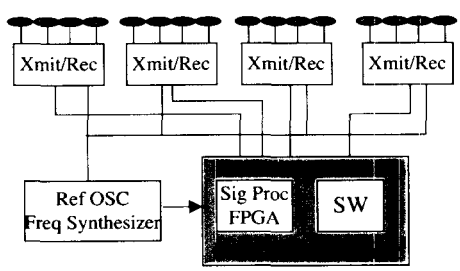
Formation Sensor Testbed (FST)

Requirements	TPF Flight	FST	Comments
Performance			
Cooperative Mode			
Operating Volume			
Angle	[illegible]	4π sr	
Range	[illegible]	16 m - 1 km	10 km for evaporation
Range Accuracy	[illegible]	0.5 m	
Bearing Accuracy	[illegible]	1 degree	
Update Rate	[illegible]	1 Hz	
Sweet Spot Cps.			
Operating Volume			
Angle	[illegible]	10 degrees	full cone angle
Range	[illegible]	20-100 m	center to center with 15-m shade
Range Accuracy	[illegible]	0.5 m	
Bearing Accuracy	[illegible]	1 degree	
Update Rate	[illegible]	1 Hz	
Non-cooperative mode			
Operating Volume			
Angle	[illegible]	4π sr	
Range	[illegible]	16-50 m	center to center with 15-m shade
Range Accuracy	[illegible]	4 m	
Bearing Accuracy	[illegible]	-	
Update Rate	[illegible]	1 Hz	
Robustness			
Fault Recovery Time			
S/C Accomodation			
Thermal Shield Geometry	[illegible]	5-20 m	diameter
Sensor Location			
Thermal Requirements			
Temperature Envir.	[illegible]		nearly constant at any point
Heat Load			
Heat Transport			
Mass			
Volume			
Power			
Robustness to other sources of radiation			

Proposed Design

AFF (Autonomous Formation Flyer) sensor

- Integrated range and bearing sensor
- Single backend processor and frequency reference
- Multiple wide-field antennas for 4π steradian coverage
- Close range radar capability for collision avoidance



Multiple sets of antennas to provide global coverage

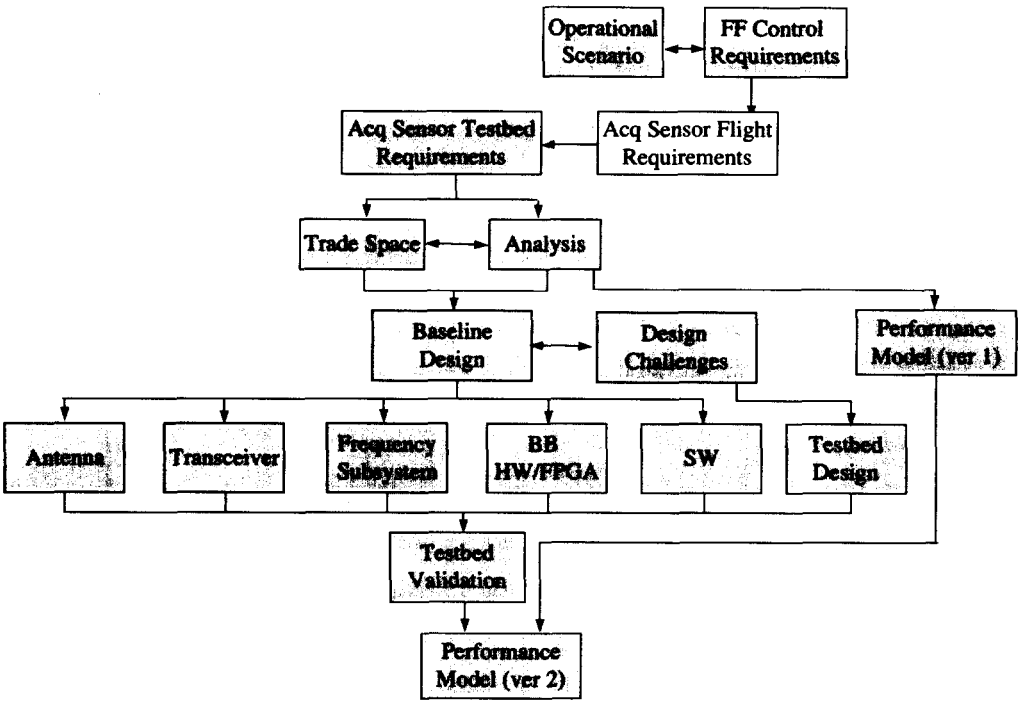
New signal structure will enable:

- An order of magnitude reduction of range error compared to what was demonstrated on the StarLight AFF sensor.
- Fine bearing angle measurement without the need for spacecraft rotation calibration maneuver.
- Fast signal acquisition for simultaneous operation of multiple spacecraft.

Potential future capabilities

- Integrated high-rate comm
- Integrated medium FF sensor
- Integrated Star Tracker
- AFF processor as S/C computer and general purpose backend processor

Development Approach

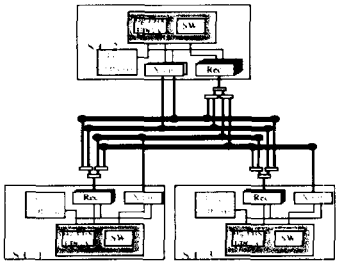
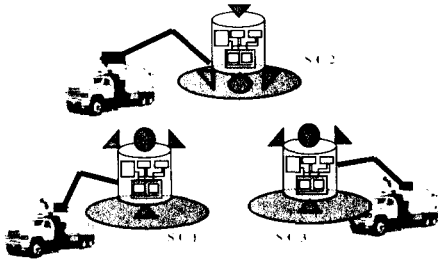


Design Challenges

Challenges	Mitigation			
	Analysis	Indoor Testbed	Outdoor Testbed	Other
• Achieve 4π coverage for both range and bearing measurements	√		√	√
• Calibrate the coarse sensor without spacecraft maneuvers	√	√	√	
• Perform adequate instrumental calibration	√	√	√	
• Maintain the array with the coarse sensor disabled on one or two spacecraft	√		√	
• Overcome multipath	√		√	√
• Acquire and track a mixture of close and distant spacecraft	√	√	√	
• Calibrate the BOC signal phase across its entire spectrum	√	√	√	
• Meet requirement for heat dissipation on the cold side of the s/c	√			√
• Choose receiving and transmitting antennas dynamically	√		√	
• Frequency subsystem design	√	√	√	

Design Challenge Mitigation Plan

FST Acquisition Sensor Analysis	FST Acquisition Sensor Testbeds

• Error Budget
  • Multipath
  • System noise
  • Link budget
  • Covariance analysis
• Signal acquisition
• Frequency system analysis
• Antenna radiation & phase pattern modeling including the effect of s/c structure
  • Analyze Ka-band AFF antenna data
  • Compare the data with simulation using the existing tools
  • Refine simulation model
  • Test and validate simulation model
	
	Indoor Functionality Testbed
	 
	Outdoor Articulated Testbed

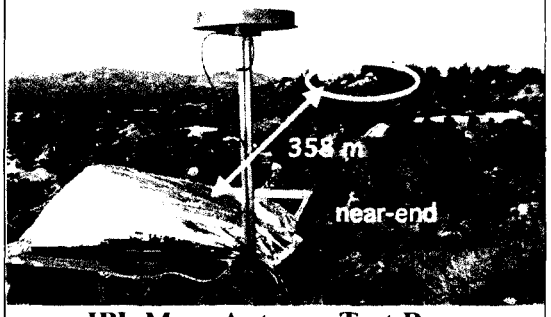
Preliminary Technology Test Results

(JPL Mesa 1200 ft range)

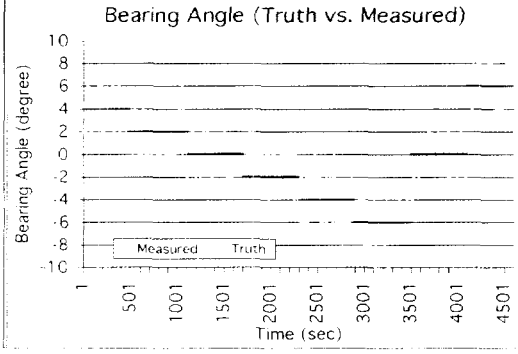
Objective:

To demonstrate the use of Binary Offset Carrier (BOC) signal to get absolute bearing angle measurement without the need for spacecraft rotation calibration maneuver. (Previous year in AFF: relative bearing angle, otherwise, calib. maneuver needed)

Requirement: 5 degree
Goal: 3 degree



JPL Mesa Antenna Test Range



Summary Results:

- Accuracy: < 2 degrees
- Precision: ~1 degree (1 σ)

Benefit for TPF:

- Significant reduction in flight system design and operational complexity.

Acknowledgement

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