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*Combined Feed-forward and Feed-back Control for Dim Star...*

**Dim star fringe stabilization demonstration using pathlength feed-forward on the SIM Test Bed 3 (STB3):**

Renaud Goulioud, Oscar S. Alvarez-Salazar, Arshak Avanesyan, Alireza Azizi, Mike Deck, Jens Fischer, Rick Graves, Yekta Gursel, John Hench, Jeff Hendrix, Brad Hines, Phil Irwin, Elizabeth McKenney, Mario Mora, Bijan Nemati, Martin Regehr, John Shaw, Robert Stephenson and George Sun.

Jet Propulsion Laboratory, California Institute of Technology

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Outline

- Introduction of STB3
- Path-Length Feed Forward (PFF)
- PFF Results
- Rejection of On-Orbit Like ACS Disturbance
- Combined PFF and Dim Star Fringe Tracking
- Lessons learned
- Status
- Links

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Introduction

- The System Testbed-3 (STB-3) is part of the technology development for the Space Interferometry Mission.
- The testbed activity is focused on the Dynamics and Control part of the mission.
- The primary objective was to demonstrate the ability of SIM to stabilize fringes of faint science stars on the science interferometer, in the presence of emulated spacecraft attitude control in the sub 1 Hertz frequency regime.
- This was achieved by "pathlength feed-forward" (PFF); using fringe information from the guide interferometers staring at bright star, to control the science interferometer.
- Initial results were presented in Munich in 2000.
- Most of the performance testing has been conducted in 2000 and 2001.

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PFF experiment on optics benches

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STB-3 Phase 1 Testbed Configuration

Actual:  $OPD = OPD_{Ext} - OPD_{Int}$

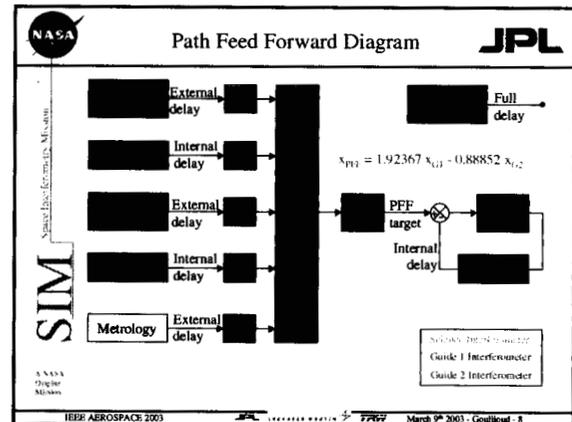
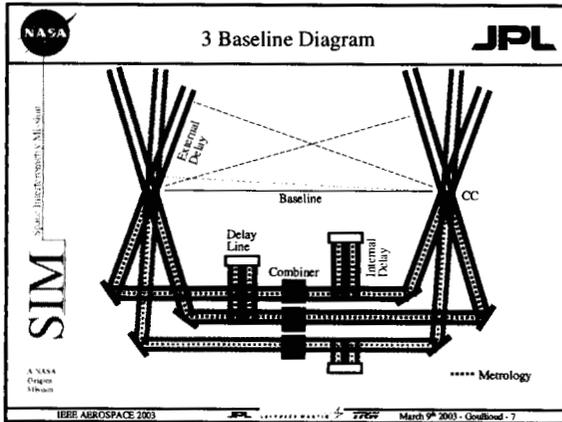
Data:  $\phi$ ,  $M_{ps}$ ,  $M_{int}$

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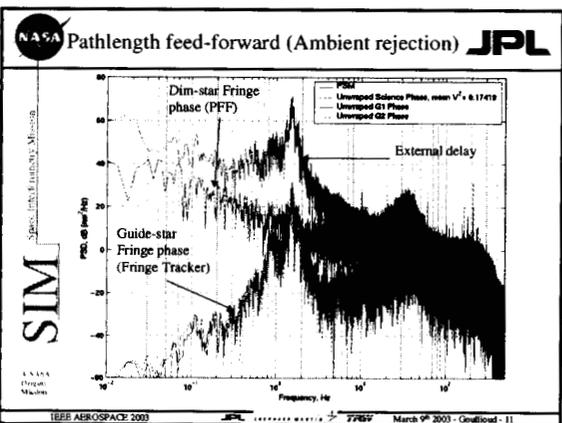
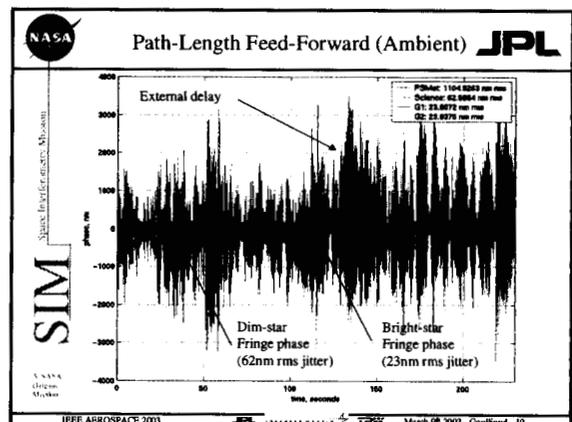
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Pathlength Feed-Forward

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- ### Path Feed Forward Summary
- Fringe stability with PFF in Science Interferometer is currently 45 nm RMS for frequencies below 1 Hz.
  - This noise floor was proven to be limited by atmospheric disturbances in the lab.
  - Steady state rejection performance of PFF has been measured for both pitch and yaw.
  - PFF Rejection levels range from 50 to 80 dB below 1 Hz.
  - On-orbit like attitude disturbance have been rejected to the ambient noise floor.
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- Space Interferometry Mission
- SIM
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- IEEE AEROSPACE 2003 JPL 77657 March 9<sup>th</sup> 2003 - Goulboud - 9



### Rejection of Induced Sine ACS Disturbances

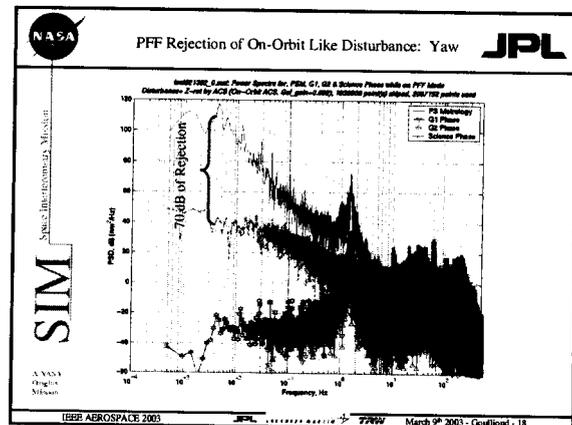
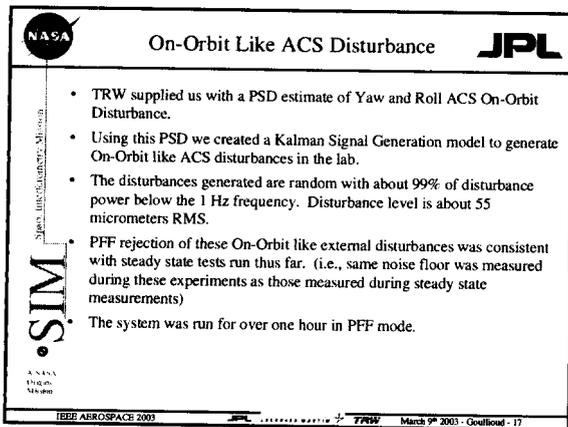
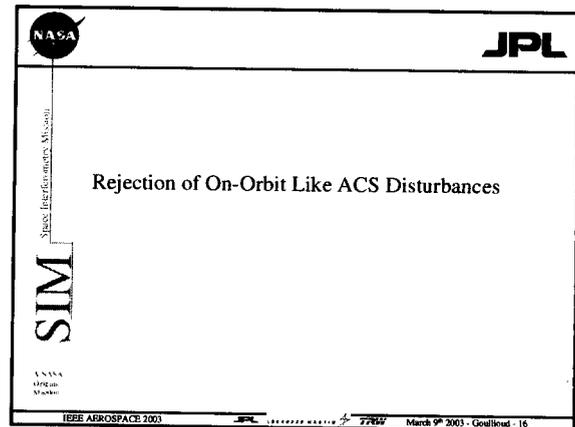
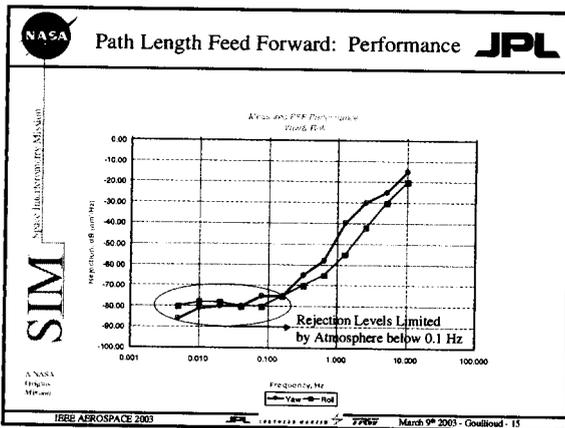
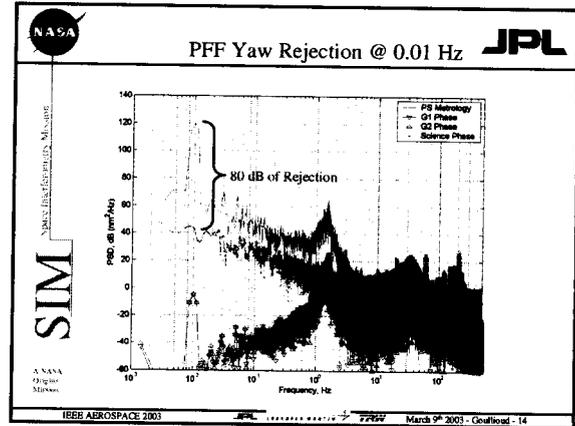
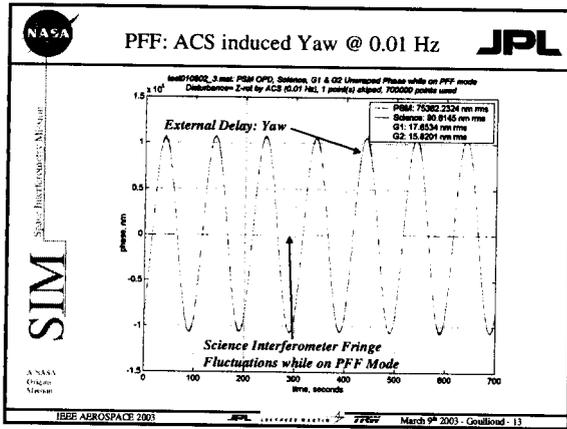
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Combined Dim Star Fringe Tracking and PFF Tests

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Dim Star Fringe Tracking Goals

- Use a very low bandwidth fringe tracking loop (in addition to PFF) in the Science interferometer to eliminate drift.
- Exact bandwidth of fringe tracking loop depends on Star Magnitude.
- In STB-3, design and implement a dim star fringe tracker for a Magnitude 15 star (i.e., 1 second integration time).
- Science interferometer drift is eliminated with addition of the Dim Star Fringe Tracker.
- Dim Star Fringe Tracker and PFF can be blended; the combined rejection is the sum of the rejections.

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Path Length Feed Forward: Performance

Measured Rejection Performance: DSFT, PFF, & DSFT+PFF

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Rejection of On-Orbit Disturbance using PFF +DSFT

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Lessons Learned

- **Fringe tracker performance** (must get good feed-back performance prior to implement feed-forward).
- **High frequency noise filtering** (to avoid feeding forward noise).
- **Sampling rate** (as fast as possible to avoid jumps).
- **Timing** (timing limits the rejection ratio).
- **Phase unwrapping** (the starlight fringe phase estimator should be robust to avoid jumping to adjacent waves).
- **Geometry** (star position knowledge limits the rejection ratio).
- **Atmosphere** (defines the noise floor for the feed-forward performance).

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Summary/Status

- PFF Rejection Performance Goals have been met.
- Performance at frequencies below 0.1 Hz is limited by atmosphere to about 80 dB rejection.
- PFF has been used to reject On-Orbit like, random, disturbances.
- Observation times of more than 1 hour have been achieved.
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Send correspondence to: renaud@jpl.nasa.gov

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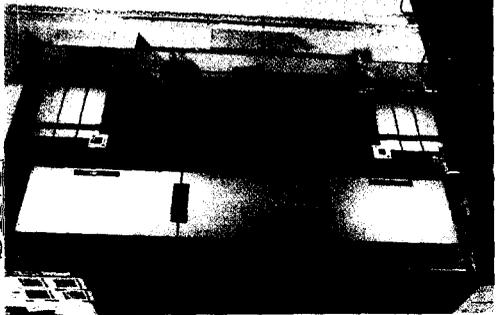
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Phase 2: PFF on the flight-like structure. JPL

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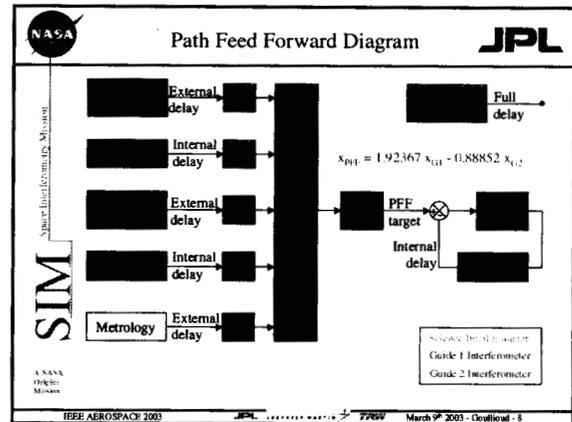
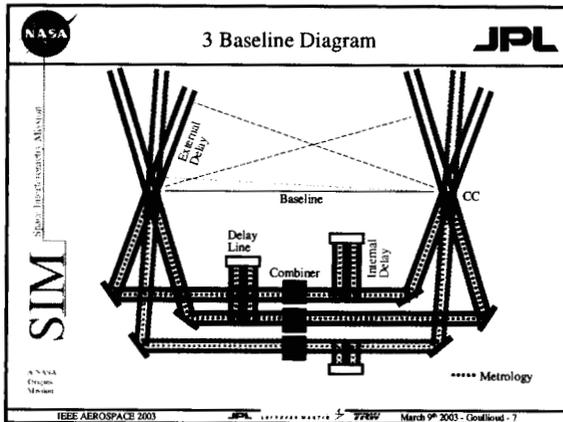
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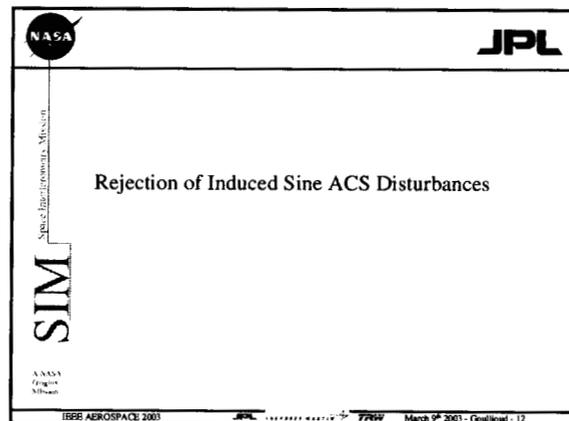
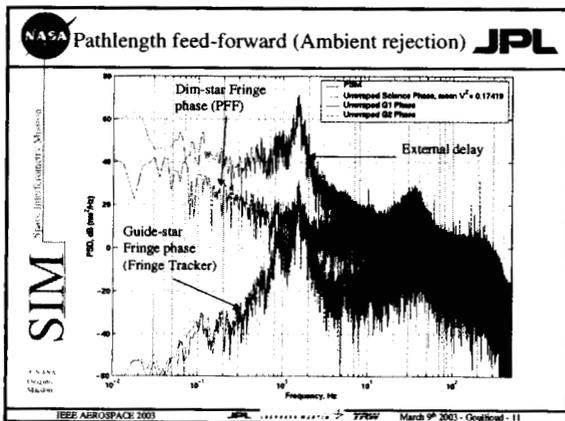
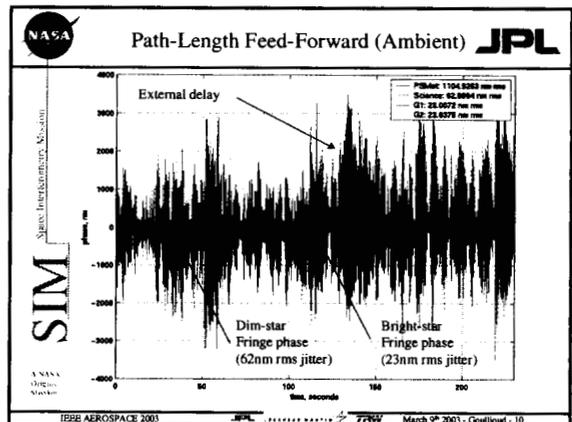
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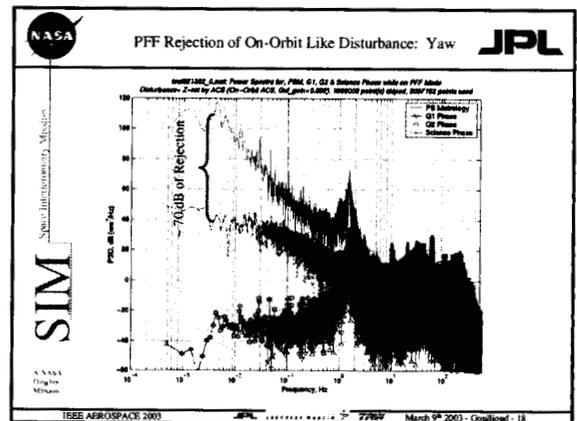
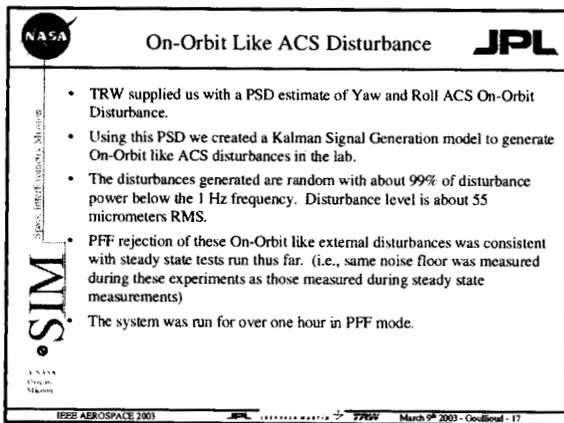
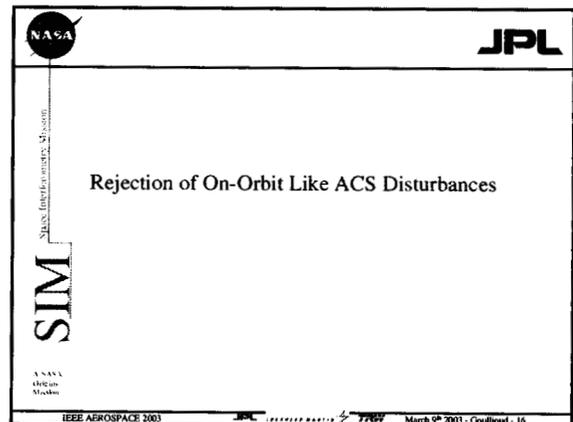
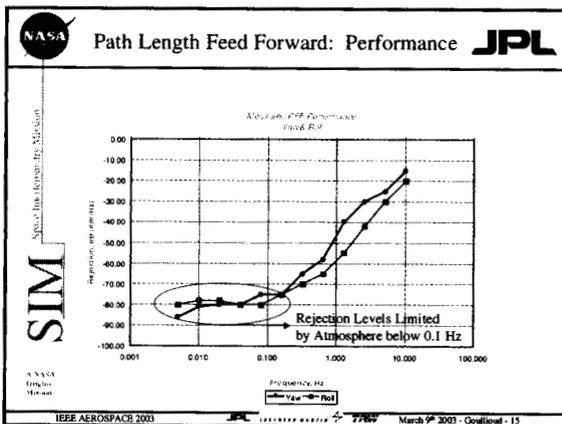
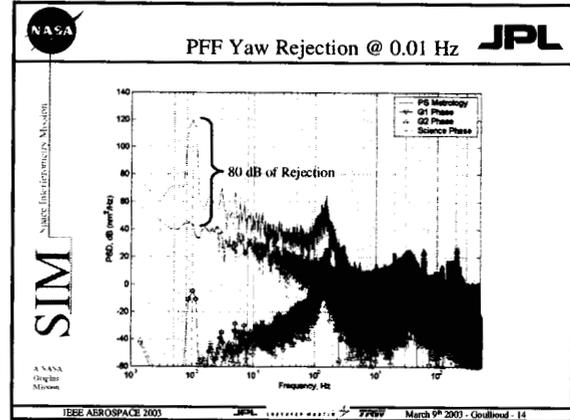
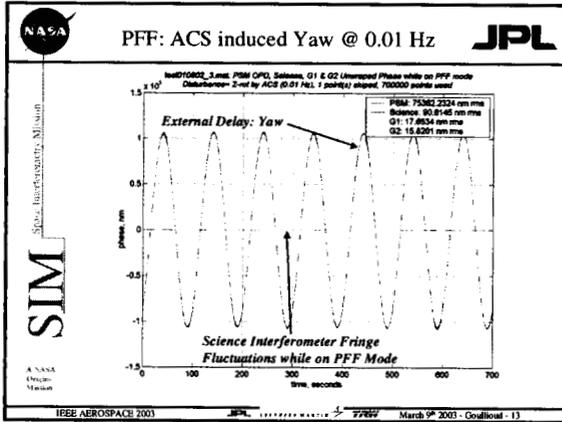


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## Combined Dim Star Fringe Tracking and PFF Tests

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## Path Length Feed Forward: Performance

Measured Rejection Performance:  
DSFT, PFF, & DSFT+PFF

Legend: DSFT, PFF, DSFT+PFF

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## Rejection of On-Orbit Disturbance using PFF +DSFT

More than 100 dB of PFF+DSFT Rejection of On-Orbit Yaw @ 0.005 Hz

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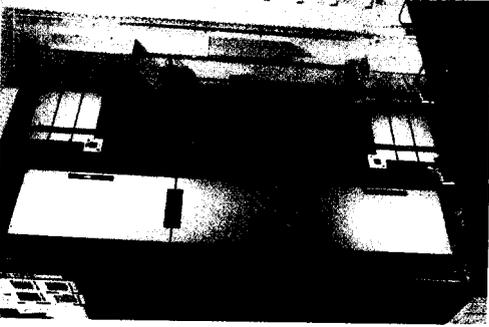


Phase 2: PFF on the flight-like structure. **JPL**

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