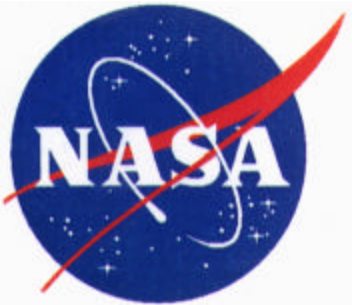


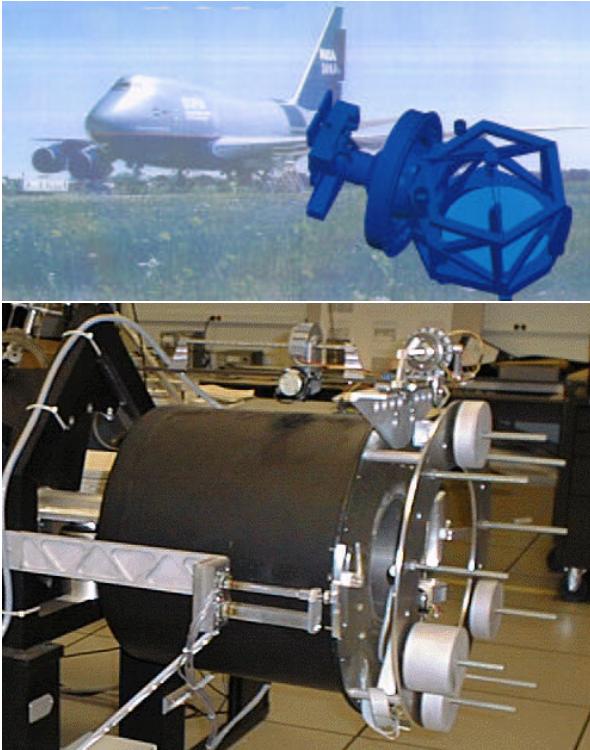
Imbalance Identification and Compensation for an Airborne Telescope

Edward Wilson, Robert Mah,
Mike Guerrero, Alex Galvagni,
Mark Wallace, Jose Winters, Noel Tan,
Richard Papasin

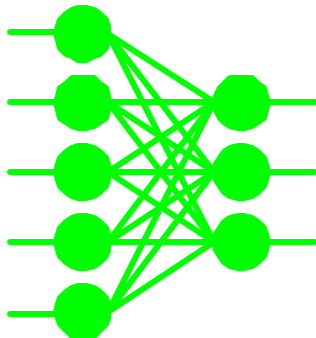


Smart Systems Lab
NASA Ames Research Center
Moffett Field, California

Outline



- Airborne telescopes - need for balancing
- Balancing procedure
 - Accurate measurement of imbalance
 - Identification of CM location
 - Placement of discrete, fixed CWs and moving CWs
- Application of intelligent-systems technology

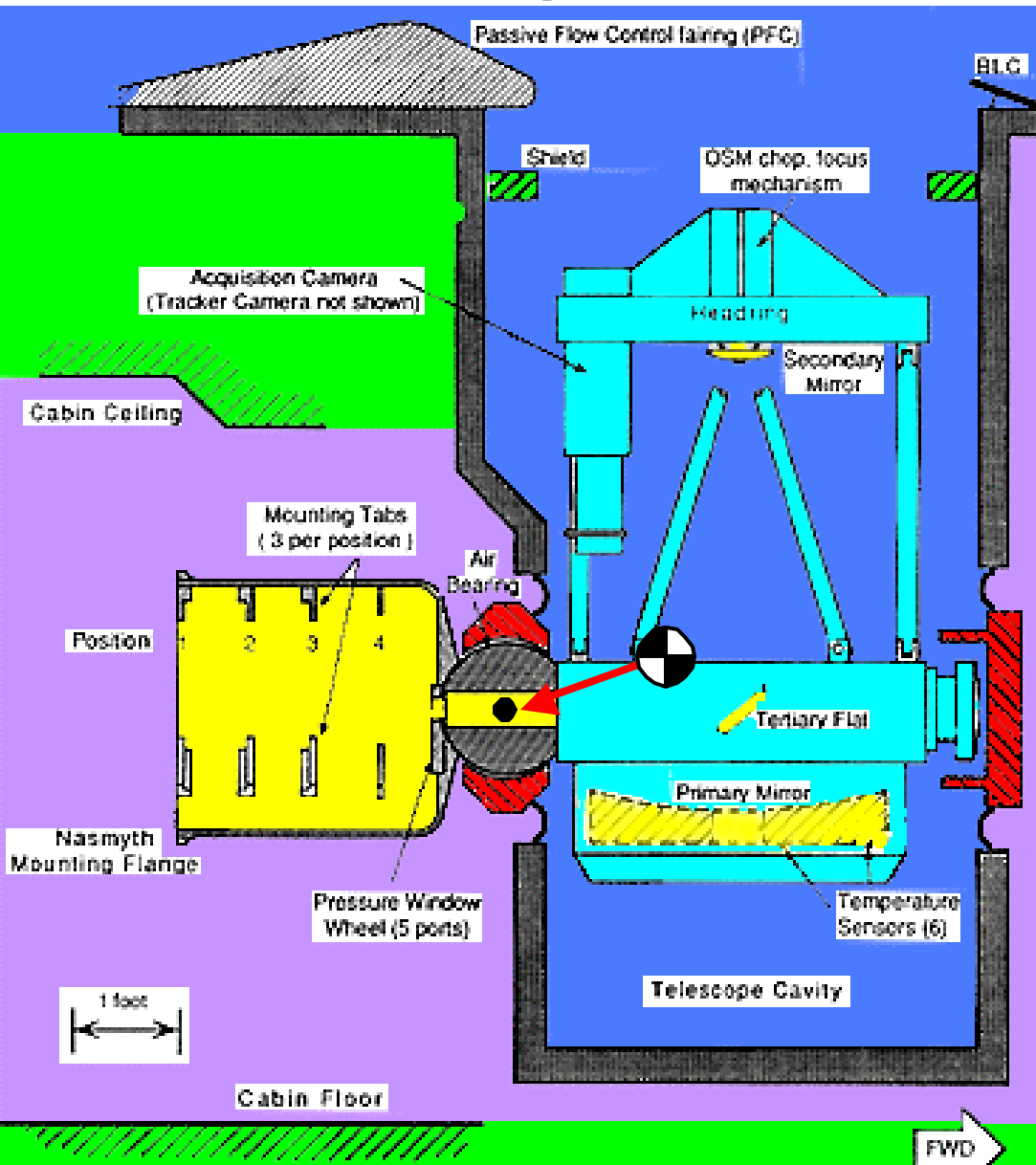


Stratospheric Observatory For Infrared Astronomy

- Due to fly in 2001
- Modified 747-SP
- NASA / DLR (Germany)
- Cassegrain telescope:
 - 2.72m diameter, 2.5m aperture
 - Image stability - 0.2 arcsec rms
 - Wavelength - 0.3 to 1,600 microns
 - Total mass - ~18,000 kg
 - Supported by 1.2m dia. Spherical air bearing
 - Drive system - brushless DC spherical segment motors



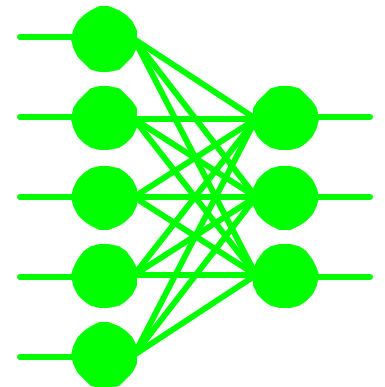
Spherical Bearing



- Isolates telescope from aircraft *rotational* motion
- Isolates telescope from aircraft *translational* motion *only if* telescope center of mass (CM) is coincident with center of rotation (CR)
- Goal of balancing is to make CM coincident with CR
- KAO telescope shown

Research Goals

- Develop telescope balancing technologies for SOFIA
 - Specific - reduce time needed for pre-flight balancing, improve balancing accuracy
 - Longer term - address in-flight/on-line balancing
- Investigate application of intelligent technologies

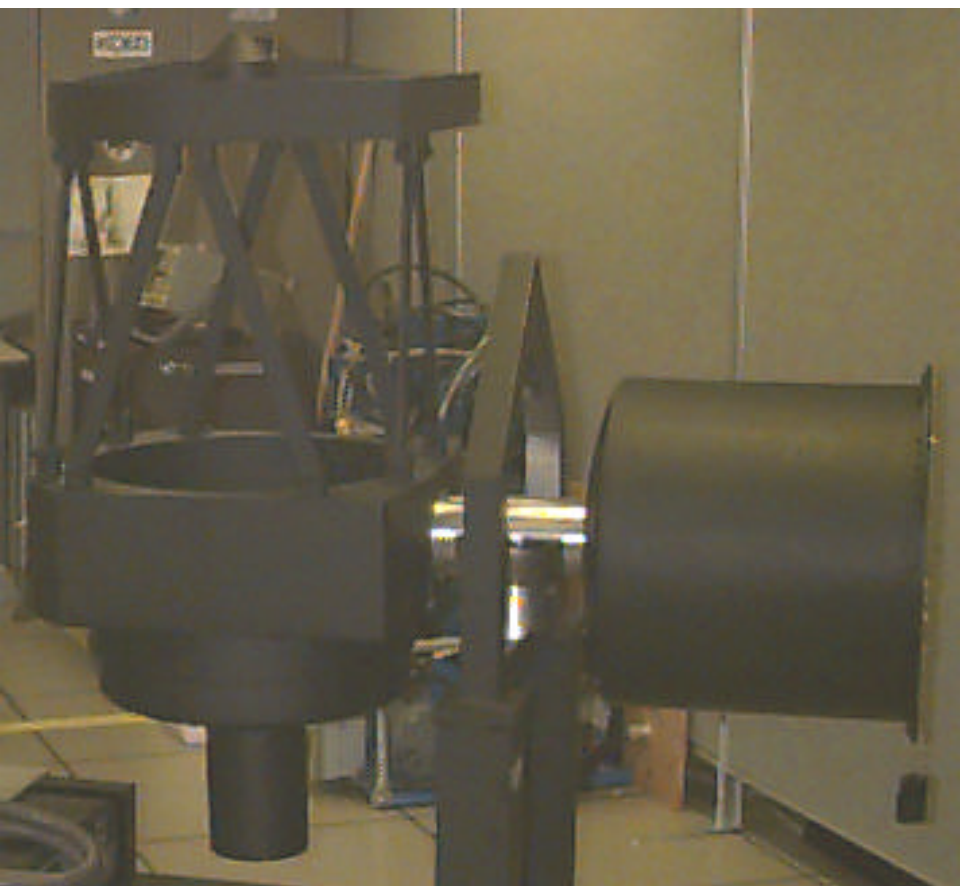
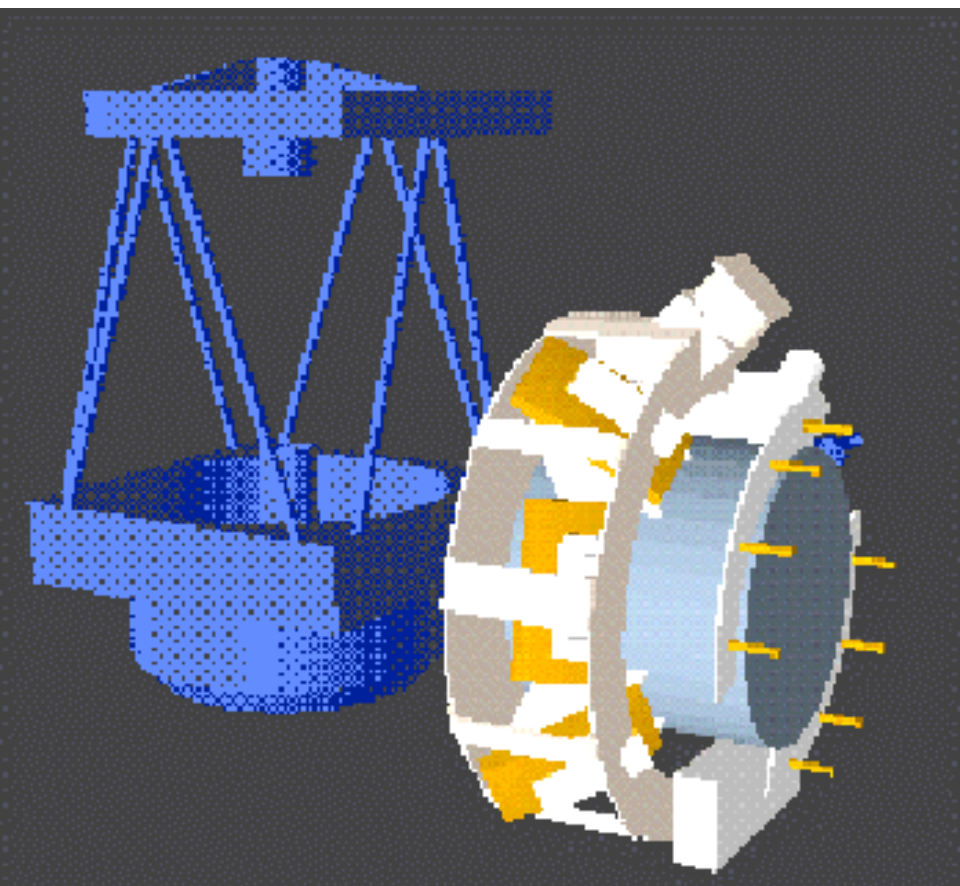


Kuiper Airborne Observatory

- Flew 1974-1995, modified C-141A
- KAO was used in this research as baseline for operational requirements, model for lab prototype
- Up to 4 hours needed for balancing



1/2-scale Laboratory Model of KAO Telescope



1/2-scale Lab. Model of KAO Telescope

Mechanical
Spherical
Bearing



Motor-driven,
Moving
Counterweights



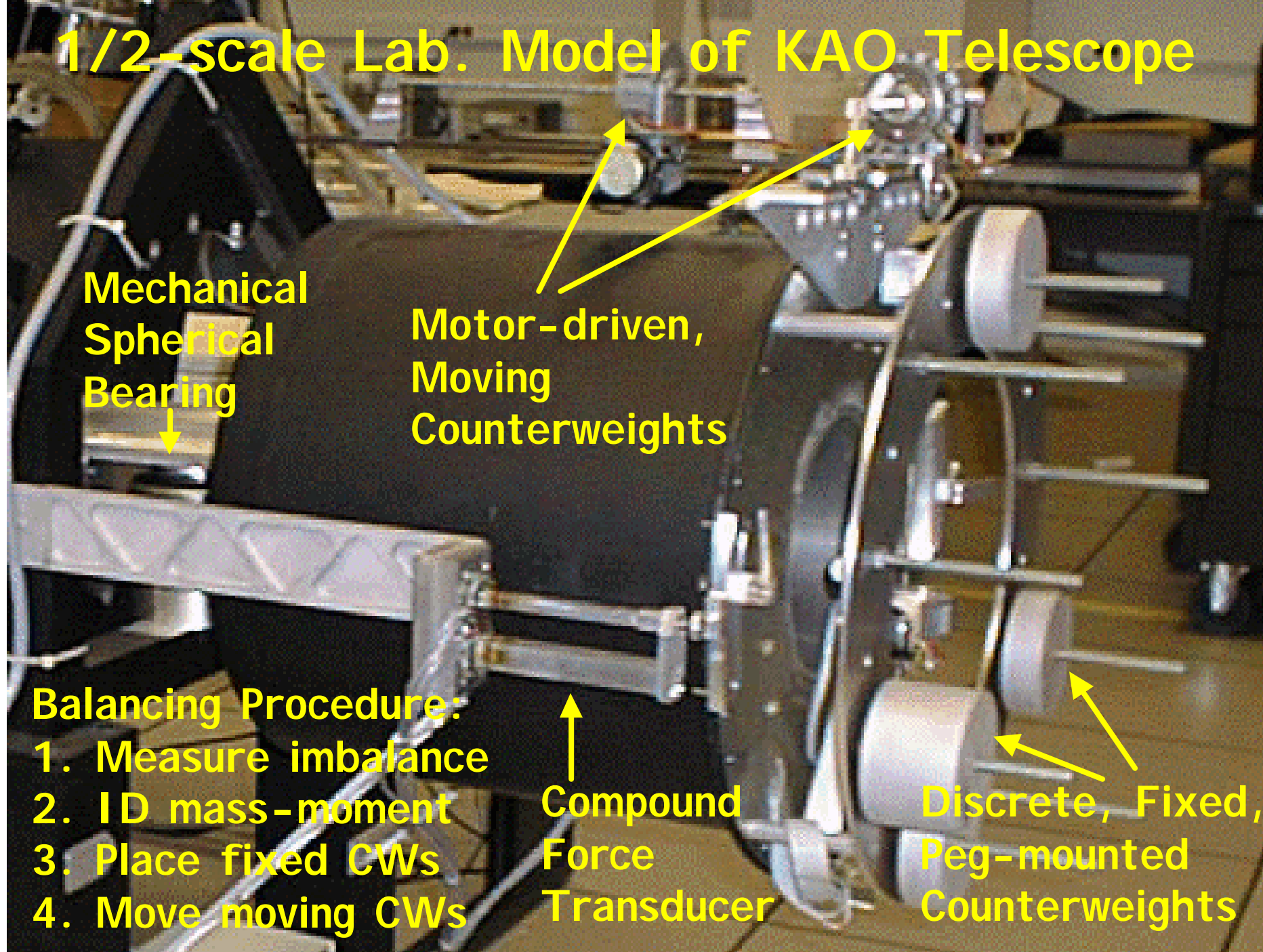
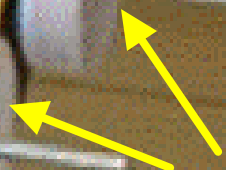
Balancing Procedure:

1. Measure imbalance
2. ID mass-moment
3. Place fixed CWs
4. Move moving CWs

Compound
Force
Transducer



Discrete, Fixed,
Peg-mounted
Counterweights



Telescope Balancing Solution

- Developed new **compound force transducer** (FT)
 - High accuracy near zero, high maximum load
- Measure imbalance forces at 2 roll angles --> I D imbalance mass-moment
- **Iterative least-squares fit to place fixed CWs**
 - Complications: (1)no negative mass, (2)limited mass/peg, (3)discrete-sized weights, (4)finite weight thickness, (5)some pegs unusable
 - Worked well. Simple. vs. Genetic algorithm, etc.
- Re-I D imbalance and drive moving CWs
- MATLAB for I D, GUI , etc. MATLAB mex functions for sensor/actuator I/O

Results Summary

- Accuracy of final balance limited by zero-drift of FTs ($\sim 0.02\text{N}$) and bearing torque ($\sim 0.05\text{N}$) --> mass of $\sim 5\text{g}$ on a $\sim 100\text{kg}$ telescope
- Balancing within ~ 5 minutes vs. 4 hours for previous balancing technology (manual)
- Solution methodology will scale up to SOFIA
- Technology development
 - Developed **compound FT** - high load, accurate near zero
 - Solution to complex **optimization** problem involving discrete-valued, limited resources (fixed counterweight placement) by **iterative application of least squares solution**

Future Research

- Work to date provides foundation
 - Mass imbalance: linear effect -> linear I D
- Scale-up/integrate with SOFIA
- Address nonlinear aspects of balancing using neural-network (NN) technology
 - Measure torques with drive motors
 - Cable effects, aerodynamic loading
 - Differentiate from mass-imbalance
- Develop “hybrid” system using both linear and nonlinear (NN) processing

