Wallops Arc Second Pointer

WASP Description
Subsystems
X-Calibur Flight
2017 Test Flight
Current Collaborations

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WASP

- WASP is a NASA developed Fine Pointing System adaptable to a variety of Science Instruments.
- Standardized System with Reusable Parts to Minimize the Cost to Users and NASA.
- Supports Multiple Science Disciplines and a wide range of Masses and Inertias.
- Currently Operational and Available for Science Collaborations
- Rotator provides coarse azimuth pointing of gondola (to within $\pm 3^\circ$)
- Fine instrument pointing achieved using gondola mounted pitch/yaw gimbal
- Two opposing gimbal hubs per axis enable sub-arcsecond stability with a design that eliminates static friction
- Control torque for each axis provided by large diameter brushless DC torque motor
- Instrument inertial attitude integrated from LN251 Fiber Optic Gyro
- Extended Kalman Filter (EKF) used to merge unit vectors from Star Tracker and other sources (e.g. sun sensor or science target) into integrated solution
- Control torques computed from modified Proportional-Integral-Derivative (PID) compensator in each axis
WASP Standard Parts

- Gimbal Frames hold Hubs, Maintain alignment critical to minimize required torque.
- Outer Frame can be used as Gondola Structure.
- Recent Developments
  - Larger Inner Frame Provides full 1 meter clearance with existing Outer Frame
  - XL Design provides ~1.2 meter clearance and has embedded hubs to eliminate counterweights

X-Calibur Larger Inner Frame
GHAPS XL Inner Frame
WASP Motor Hubs and Resolver Hubs

- Each Axis uses One Motor Hub & One Resolver Hub.
- Constantly Rotating central shaft eliminates static friction (Stiction) when direction is reversed.
- Shaft Rotated with Electric Motor through Reduction Gear.
- Motor Hub has large diameter Torque Motor which provides the control torque.
- Resolver Hub has resolver which provides Angle Measurement between two halves of the Hub.
- Hubs support full mass of Pointed Structure and 10 G loading.
Avionics Deck
- ~21” x ~17” aluminum deck

3 Axis Fiber Optic Gyro
- Northop Grumman (NG) LN-251 Inertial Navigation System
- Used by WASP as Inertial Rate Unit (IRU).
- NG installed new firmware in 2016 reducing noise and improving pointing performance.
Dynamic Balance Trim Weights

- Three Dynamic Balance Trim Weights flown, one in each Axis.
- Commanded from Ground if needed.
- Brass Weight driven by small DC motor.

Caging Mechanism

- Linear Actuator and electric motor driven cam provide redundant methods for releasing and recaging.
- Uncage - Linear Actuator shaft retracts or motor cam pushes latch hook.
- Cage – Shaft extended, hook spring loaded or drive into place, then extend shaft.
CARS – Celestial Attitude Reference and Determination System
- COTS camera and processor, custom light baffle
- Low-cost system for providing attitude inputs into WASP Control System

Operational specifications
- Point Grey Camera, 100 mm Stingray Lens, RTD flight processor
- Field of View: 5.9 x 4.4 degrees
- Tracking solutions: 10 Hz
- Supplies target matched unit vectors or quaternions, depending on the application, over Async Serial or Ethernet interface
WASP Test Flights

- 5 Test Flights conducted between 2011 and 2014
- All 5 from Fort Sumner, New Mexico
- Three Flights included Science Instruments
  - 2 flights with LASP Earth Science (HySICS)
  - 1 flight with GSFC Planetary and Exoplanet Science (OPIS)
- All 5 demonstrated arc-second pointing
First Science Mission with WASP

PI Henric Krawczynski, Washington University in St. Louis (WUSTL)
- Measure Linear polarization of hard X-rays in the energy range of 25-70 keV.
- 255 shell X-ray focusing mirror and a rotating Polarimeter.
- Rigid truss to maintain alignment between mirror and the detector 8 meters away
- Pointing Requirements
  - Compute attitude with knowledge uncertainty within 30-asec (3-sigma)
  - Hold X-ray mirror boresight to target within 30-asec (3-sigma)

September 17, 2016, flight duration 24 hours and 37 minutes
- Fort Sumner, NM. Longest flight of WASP to date
X-Calibur Science Flight

X-Calibur High Elevation Pointing Test at Fort Sumner

X-Calibur on Launch Vehicle

X-Calibur Pointing during Flight
X-Calibur Pointing Performance

- Tracking errors consistent with preflight simulation and ground testing – sub-arc second.
- Star Tracker Residual provide indication of attitude estimation errors that contributes to absolute pointing error.
- Roll coupling into pitch/yaw axes indicative of misalignment between Star Tracker and Inertial Rate Unit.
- Able to identify misalignment by batch processing 5-10 min segments of flight data.

Post Flight Improvements
- Misalignment correction technique ground tested that eliminates roll coupling.
- New centroid algorithm ground tested that improves daytime performance with high ambient background levels.
- Both to be tested on 2017 WASP Test Flight.
WASP 2017 Test Flight

- Combined with CSBF LDB Test Systems
- Includes refurbished parts of X-Calibur, OPIS, and Test Flight Two
- Evaluate daytime Star Tracker performance improvements.
- Evaluate flight prototype GHAPS Baffle for star tracker.
- Evaluate GHAPS configuration of modified WASP Avionics mounting locations.
- Sept. 2017 Fort Sumner

WASP Avionics in GHAPS OTA Configuration

GHAPS Baffle and Star Tracker

LN251

10” square steel tube used on TF1 and TF2

Trim Weights
Current WASP Mission Support

PICTURE-C
Planetary Imaging Concept Testbed Using a Recoverable Experiment – Coronagraph
- PI Supriya Chakrabarti U Mass Lowell (UML)
- 60 cm Telescope with Coronagraph to Image Debris Disks of Nearby Systems
- Flights planned for 2018 and 2019.

GHAPS
Gondola for High Altitude Planetary Science
- NASA – GRC, MSFC, GSFC, WFF
- Developing a Reusable Gondola Platform for Planetary Science Instruments
- One Meter optical telescope, UV, IR, visible
- Initial flight planned for 2020.