Overview of the Gondola for High Altitude Planetary Science (GHAPS)

Presented By:
Roy Young
Marshall Space Flight Center
roy.young@nasa.gov
Background

- The GHAPS project resulted from the 2011 Decadal Survey describing balloon-based planetary science as a high priority to enable achievement of long-term planetary goals.

- In January 2012, GRC led a workshop to assess the potential of planetary science missions from a balloon-based observatory laying the ground work for the GHAPS concept (Final Report - NASA/TM—2016-218870).

- Super-pressure balloon development has increased the planetary science potential for a balloon based observations.
  - Enabling missions up to 100 days with day/night cycles from Wanaka New Zealand.

- GHAPS Mission Concept Review (MCR) and System Requirements Review (SRR) were successfully completed in December 2015.

Outlines plans for space and ground based exploration ten years into the future.
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<th>GOALS</th>
<th>OBJECTIVES</th>
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<td><strong>1.0</strong>&lt;br&gt;Collect decadal-class planetary science from a balloon-borne platform, with particular emphasis on observations not practical or possible from the ground, or airborne/space-based assets.</td>
<td><strong>1.1</strong>&lt;br&gt;Observe planetary objects in the UV, visible, near to mid-IR spectrums (approximately 0.3 to 5 μm wavelengths).&lt;br&gt;<strong>1.2</strong>&lt;br&gt;Point to and track planetary targets with sub-arcsecond accuracy.&lt;br&gt;<strong>1.3</strong>&lt;br&gt;Observe planetary targets for several hours up to 100 days.</td>
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<td><strong>2.0</strong>&lt;br&gt;Reduce the cost and time required for development of balloon-borne planetary science missions.</td>
<td><strong>2.1</strong>&lt;br&gt;Fly balloon-borne planetary science missions at a frequency of once per year.&lt;br&gt;<strong>2.2</strong>&lt;br&gt;Successfully complete 5 flight campaigns with refurbishment costs for each less than 20 percent of the original hardware development cost.</td>
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<td><strong>3.0</strong>&lt;br&gt;Provide a balloon-borne platform to support a broad envelope of planetary science mission needs as described in the Decadal Survey.</td>
<td><strong>3.1</strong>&lt;br&gt;Provide a platform with standardized interfaces and functional characteristics for instrument packages that meet an envelope of balloon-borne planetary science mission needs.&lt;br&gt;<strong>3.2</strong>&lt;br&gt;Provide an adaptable platform for conventional, long duration, and ultra-long duration missions through the Columbia Science Balloon Facility.</td>
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Key drivers for balloon-borne investigations:

- **Access to wavelengths that are inaccessible** with ground-based telescopes
- **Temporal coverage**
- **High spatial resolution** at short wavelengths and **high spectral resolution** from UV to IR wavelengths
- **Science trades focused on maximizing the # of Decadal Science questions addressed**
- **Clear break points** between increased cost and incremental science return
  - 1 m Aperture
  - Sub-arcsecond coarse pointing stability
  - Float altitude ≥ 100k ft
- **Presented these parameters with other expected conditions to SIDT**
  - SIDT evaluated the platform for science ability
  - SIDT evaluated the types of instruments suitable to capture diverse science objectives
Key results from SIDT

- The **capability to track objects at non-sidereal rates** is critical for many solar system targets.

- Sensitive IR detectors require temperature of ~30 K.

**Imaging**

- A fine guiding capability (**jitter < 30 milliarcsec RMS**) is critical for a number of measurements, particularly at UV and visible wavelengths.

- High image acuity (i.e. **diffraction-limited imaging**) over all wavelengths, and a **field of view of at least 3’**

**Spectroscopy**

- A range of desirable instrument modalities, including **long slit (>10”) spectroscopy** for both UV and IR.

- Two dimensional spectroscopy (integral field unit or hyperspectral imaging).
GHAPS Overview

• Develop a Re-useable Balloon Platform to meet Planetary Science Goals and Objectives as outlined in Decadal Survey

• 1 meter Optical Telescope Assembly (OTA) with Sub-arc-second pointing capability

• Designed for a minimum of 5 flights from any Balloon Program Office (BPO) launch location

• Designed for mission durations up to 100 days

• Planetary Science Observations 300-5000 nm

• Low cost refurbishment between flights

• The first flight is planned for Fort Sumner, New Mexico in the fall of 2019

• The objective of the first flight is to demonstrate performance and conduct science observations

• A competitive process will be used to select investigators and the GHAPS Instrument Suite.
GHAPS Challenges

• Operating in Gravity field
  • If space-based, gravity wouldn’t be an issue – structure could be made lightweight
  • If we were ground-based, weight wouldn’t be an issue so structure could be made stiff
  • Our requirement is to be stiff yet light

• Dual Wavelength (UV-Vis and IR)
  • Conflicting thermal requirements for the combined single-mission with no active cooling
    • UV-Vis diffraction limited performance at -30 °C
    • IR observations at -50 to -60 °C
  • Mirror coating selection for high reflectivity and low emissivity across wide spectral range (.3 to 5 μ)
Two Types of Balloons

Super-Pressure Balloon maintains nearly constant volume
- Allows Ultra Long Duration Balloon (ULDB) Flights
- Provides stable altitude Long Duration Balloon (LDB) flights at mid-latitudes

Zero-Pressure Balloon changes volume due to temperature changes
- Used for Conventional Flights and Polar LDB Flights
GODDARD SPACEFLIGHT CENTER (GSFC)

• The GHAPS Project Scientists reside at GSFC.
  – The project scientists translate science goals into science requirements,
  – develop design reference mission scenarios as part of GHAPS development cycles,
  – assist in mission design and operations strategy,
  – support development of instrument calls and science mission call for proposers,
  – set up the GHAPS data processing and distribution system,
  – coordinate with potential and active users and identify future platform improvements to increase science return.

• GHAPS Flight Software Lead resides at GSFC
  – Responsible for management, development, test, and flight support of the flight and mission operations software for GHAPS.
GHAPS Partners Provide Key Subsystems Wallops Arc-Second Pointer (WASP)

WALLOPS FLIGHT FACILITY (WFF) - GSFC

- WFF selected based on analysis of RFI responses and HQ review held October 2015.
- In-house build and test planned at WFF.
- GHAPS/WASP simulations predict sub-arc-second pointing is achievable.

Scope:

- WASP development, test, qualification, assembly integration and test support, flight support. (In – House)
- WASP Sustaining engineering, including refurbishment between flights.
- WFF to provide support for integrated testing and mission operations.
- The WASP is controlled and monitored from a control center at the NASA Wallops Flight Facility (WFF).

Updates since MCR/SRR:

- XL Design provides ~1.2 meter clearance and has embedded hubs to eliminate counterweights.

FEATURES:

- Sub-Arc Second pointing capability
- 815 lb mass allocation
- Fine instrument pointing achieved using gondola mounted pitch/yaw gimbal
- Outer Frame incorporated into Gondola Structure
- Inner Frame and star tracker interface with OTA.
- Gimbal Frames support Hub and Maintain alignment.
- LN251 Fiber Optic Gyro
- WASP Avionics
INSTRUMENT APPROACH:

• Two instruments are being used as design reference mission instruments (300-5000nm wavelengths).

• Science Instrument Definition Team (SIDT) organized by HQ to define and prioritize science instruments for GHAPS.

• Preliminary report has been released and is currently under review – September, 2016.

• HQ call for instruments – October Release

• NASA GRC to manage instrument development.

Scope:

• Instrument developer responsible for development, test, qualification, assembly integration and test support, flight support.

• Instrument Sustaining engineering and refurbishment between flights

• Instrument developer to provide support for integrated testing and mission operations

DESIGN REFERENCE INSTRUMENT FEATURES:

UVVis

• UV and Visible instrument (300–700 nm) (includes fast steering mirror) developed by Southwest Research Institute (SwRI)

BRISSON IR Camera (BIRC)

• Near to mid IR instrument (2.5–5 microns) developed by APL
GHAPS Partners Provide Key Subsystems
Optical Telescope Assembly

MARSHALL SPACE FLIGHT CENTER (MSFC)

• MSFC selected based on RFI responses.

Scope:

• Optical Telescope Assembly (OTA) development, test, qualification, assembly integration and test support, flight support. (In – House)

• OTA Sustaining engineering, including OTA primary mirror recoat and refurbishment between flights

• MSFC to provide support for integrated testing and mission operations

Updates since MCR/SRR:

• Addition of Shack-Hartmann wavefront error sensor for OTA secondary mirror control

• Tailored OTA primary mirror zerodur for improved UVVIS performance at cold temperatures.

• Instrument-OTA integration at MSFC - Xray Cryogenic Facility (XRCF) for coupled environmental optical alignment test.

OTA PDR – 10/27/16

FEATURES:
• 14.056-m focal length
• 1-m clear aperture
• 632 lbs weight allocation
• Ritchey–Chrétien design
• Metering structure - composite, IM7-8552, with metallic inserts at high stress points
• 0.3 – 5 µm pass band
OTA Characteristics

- 14.052-m effective focal length (EFL) Ritchey-Chretien (RC) design
- Hyperbolic primary and secondary
  - Primary will be a contracted item – size exceeds in-house fabrication capabilities
  - Secondary will be fabricated in-house (fall-back is to contract)
- Design influenced by existing UV-visible and IR instruments
- OTA focal length is a compromise between short focal length desired for IR instrument and long focal desired by UV-visible instrument
- **Primary Mirror procurement:**
  - [https://www.fbo.gov/](https://www.fbo.gov/)
Primary Mirror and Supports

Primary Mirror:

Mirror Support
- Athermalized Whiffletree and Tangent Bar mounts
- Mount members sized to match secondary mirror despace
(M1) Composite Cell

» (M1) Box Frame
- 39-Piece Composite
- 2 WASP Interface Hubs
- 6 Datum A Interface Pads
- 3 Tangent Bar Mounting Plates

» (M1) Cruciform
- 9-Piece Composite
- Interface Hardware
  - Plates, (M1) Whiffle-Tree
  - Pins, (M1) Light-Baffle
M1 & M2 Metering Tubes
- Composite barrel, with molded flanges (bonded to structure)
- 16-Ply, .115" Thick

Light-Baffles
- Composite Sheet
- 8-Ply, .058" Thick

Sunshade Shroud
- 50” Length
- 46” ID
- IM7/8552 Carbon Fiber
- 8-Ply, .058” Thick
Secondary Assembly

Composite Sheet head Ring
- IM7/8552 Carbon Fiber
- 32-Ply, .230” Thick
- 16-Ply, .115 Thick radial supports

Secondary Mirror
- 220 mm OD
- 25.95 mm Thick
- Zerodur

PI H-824K023 Hexapod
- Travel +/-12.5 mm (X,Y), +/- 22.5 mm (Z)
- Tilts +/- 7.5° (X,Y), 12.5° (Z)
- Minimum X,Y,Z motion increment 0.3 µm
- Minimum tilt increment: 3.5 µrad
- 10 kg load (self-locking feature)
- Vacuum compatible to 1 x 10⁻⁶ torr
- Motor type: Brushless DC
- Operating temperature range: 0 to 50°C
Primary Mirror (PM) Gravity Error

- SFE when pointing horizontally; defocus removed; 632.8nm waves
- SFE when pointing vertically; defocus removed; 632.8nm waves

- All other pointing angles will have surface figure error (SFE) that is a weighted average of these two cases
- Asymmetry in the Vertical pointing case is caused by tangent bar asymmetry
- The SFE over the mirror’s surface is RMSed to determine the RMS SFE
Deflection of the Telescope:

Deformation of the telescope due to a 1g loading in the \(-y\) direction, scaled 2000 times.

Deformation of the telescope due to the Worst Case thermal loading, scaled 500 times.