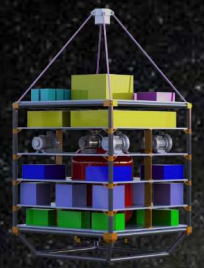
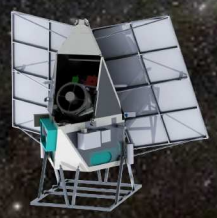
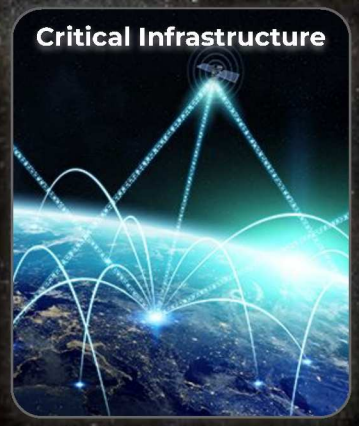
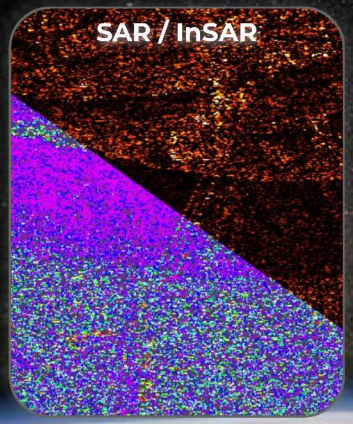


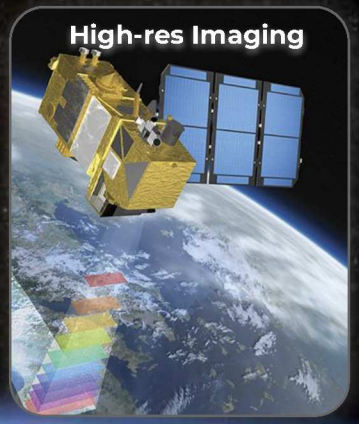


STARSPEC TECHNOLOGIES

Rethink Space—
Transform **the World.**







Space-based solutions that
empower discovery and **inspire innovation.**

Consulting | **Fabrication** | **Manufacturing** | **Certification** | **Support** | **Operations**

STARSPEC-PIVOT

↳General Purpose Balloon-borne Rotator

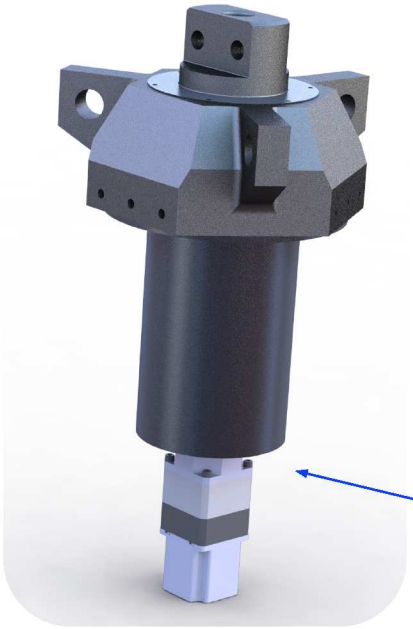
- ↳Standard launch provider interface
  - Accommodate CSBF and CNES balloon launch interfaces
- ↳Launch provider mechanical certification
  - Provide full certification and proof-testing adhering to CSBF and CNES standards
- ↳Multiple "hat" configs (35–50 lbs assembled)
  - 2, 3, or 4 rope suspension gondolas
  - Rope suspension or rigid-body connection
- ↳Multiple weight-class payloads
  - Ultralight (0.3–1 klb), Light (1–2.5 klb), Medium (2.5–5 klb), Heavy (5–8 klb)
  - Material based on weight-class

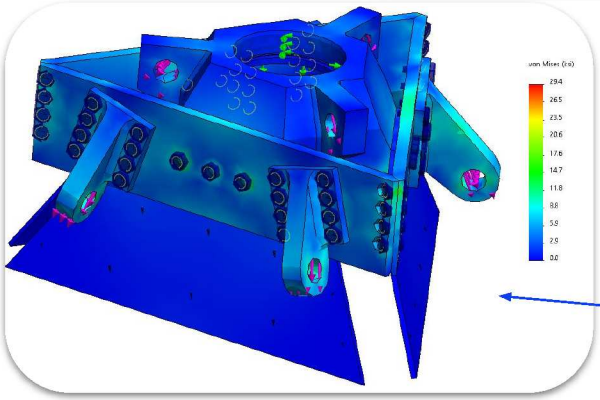
Heritage:

- SuperBIT '15, '16, '17, '18, '19
- Spider '14; BLAST '03, '05, '06; BLASTPol '10, '12; BLAST-TNG '19
- BOOMERaNG '98, '01

Currently implementing on:

- Spider2 '22; SuperBIT '23; EXCITE '23, '24
- TAURUS '24; BLAST-Obs, BEGINS, POEMM
- ADAPT (WUSTL), PICTURE-J, SAKHMET





Launch Vehicle Interface

- Standard, certified adapter to various launch vehicles
- Accommodates both CSBF and CNES launch vehicles
- Certified and flight-tested with heritage from multiple flights

U-Joint Assembly

- Universal joint connects flight train (truck plate) to Pivot
- Mitigate launch- & chute-shock
- 20+ years of flight heritage

Built-in Feedback Control

- Velocity / position / torque control
- Optimized modes for pointing / scanning / constant rotation
- High accuracy pointing reconstruction
- Direct GPS compass integration (NMEA standard)

Analysis & Certification

- Full payload analysis through Pivot connection in all loadings
- Up-to-date with current launch provider requirements
- High margin design and multiple flight heritage over 20+ years

STARSPEC-SPS

↳High-efficiency space-based power system

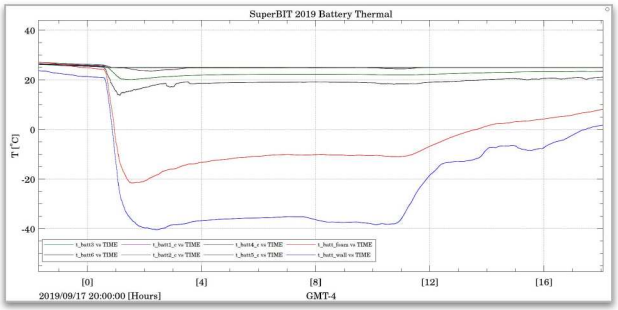
↳Fully COTS system with robust Housekeeping stack
- Configurable and continuously monitored closed-loop charging & thermal control
- COTS components easily replaceable in the field
- Housekeeping stack integrates over the network with flight systems in standard TCP format

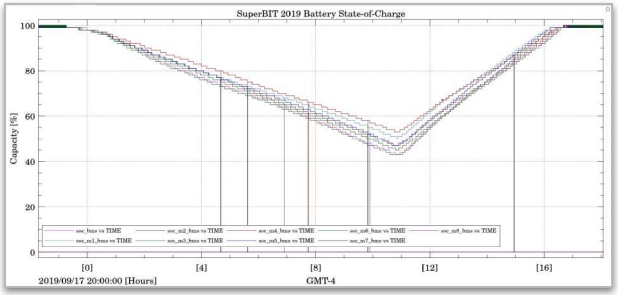
↳Scalable for wide range of payload requirements
- 250 W, 500 W, 1 kW, 2 kW,... power generation, charging, and storage systems
- Multiple independent switched output channels for payload subsystems
- Modular array design for multi-panel coverage

↳Designed for SPB Gondolas and LEO SmallSats
- Radiation tolerant for targeted mission profiles (3-5 years nominal, 300–500 km orbit, pending)

Heritage:
- SuperBIT ‘15, ‘16, ‘17, ‘18, ‘19; BLAST-TNG ‘19

Currently implementing on:
- SuperBIT ‘23; EXCITE ‘23; TAURUS ‘24
- BLAST-Obs, BEGINS, POEMM, PICTURE-J
- SmallSats: TARDIGRADE, InspireSAT, LUVS





Scalable Modular Design
- Configurable power generation / storage to meet payload and pointed Gondola requirements for Az-rel-Sun
- Lightweight and stiff panel design
- 24 VDC or 48 VDC standard configs; Pb-acid and LI-ION configurations
- N-channel individual power switching and 16 bit current monitoring
- 20 A per channel; inductive load tolerant

Active Thermal Control
- Built in thermal regulation to maximize battery performance
- Suitable for day-night cycles for SPB Gondolas or LEO SmallSats
- Housekeeping thermometry and auxiliary heaters available from SPS Housekeeping stack

Robust Performance
- Demonstrated day-night cycle performance at depth-of-discharge that maximizes lifetime (> 50000 cycles*)
- Built-in margin for roll-out, launch, ascent, and pointing excursions
- Launch Provider controlled main breakers for safe termination / orbital deployment

DATA-RECOVERY-SYSTEM

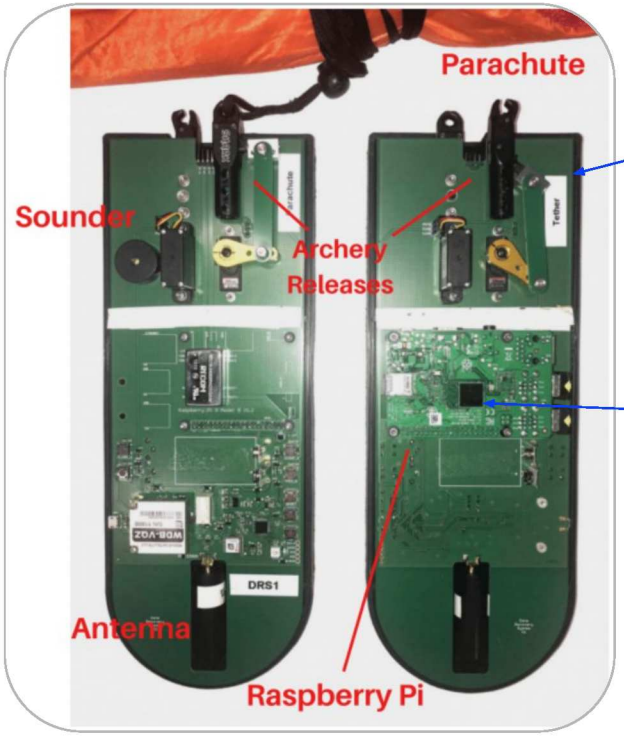
↳Data drop by tracked parachute

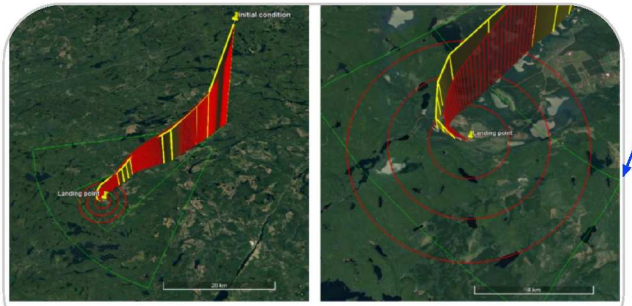
- ↳Standard approved drop design
  - CNES- and CSBF-approved design and CNES-flown
- ↳Standard payload interface
  - Quick-release ethernet and power
  - Storage up to 5 TB per unit
- ↳Full GPS and transponder tracked for recovery
  - *"PyBalloon"* software for drop forecasting
  - Wind prediction models for high fidelity tracking and recovery
- ↳Low component profile and mass (< 2 kg per unit)
- ↳Scalable—multiple units equipped per flight

Heritage:
- SuperBIT '18, '19

Currently implementing on:
- SuperBIT '23 (SPB)

Seeking involvement with:
- NASA Wallops Collegiate Balloon Competition's "FLOATing DRAGON"





Deviation: ~600m

<u>Easily Manufacturable Design</u>
- Leveraging consumer-based COTS—minimal custom components
- PCB board assembly TVAC and flight tested for stratospheric operations
- Built-in deployment terminator and parachute

<u>On-board Capabilities</u>
- Network-interface with payload for up to 5 TB data storage per unit
- On-board OS for in-flight data monitoring
- Computing resources available for on-board computing / analysis

<u>High Fidelity Tracking</u>
- GPS tracking and transponder on-board
- Ground-based *"PyBalloon"* prediction software incorporates weather models for wind trajectory prediction
- Demonstrated 600m prediction fidelity when dropped from 35 km altitude (SuperBIT '19, CNESS)

<u>Full Capabilities & Flight Results available:</u>
- "Download by Parachute: Retrieval of Assets from High Altitude Balloons" - Sirks 2020

STARSPEC-TRACKER

↳High accuracy modular star camera

- ↳Fully COTS solution backed by powerful software
  - Astronomy.net standard catalogues for arcsecond accuracy
  - Differential target star tracking at high rate (50 Hz) at sub-arcsecond (<0.2” fwhm)
  - Plug-and-play network interface
- ↳Full performance in day or night at float / orbit
  - Wide field of view for guaranteed lock
  - Filter configs to optimize for sky backgrounds
- ↳Space qualification for LEO SmallSats
  - Radiation tolerant for targeted mission profiles (3-5 years nominal, *pending*)
- ↳Low component profile and mass (< 2 kg per unit)
  - Fleet- / constellation scalable
  - High heritage in space environments

Heritage:
- Spider ’14; SuperBIT ‘15, ‘16, ‘17, ‘18, ‘19

Currently implementing on:
- Spider2 ‘22; SuperBIT ‘23; EXCITE ‘23, ‘24
- TAURUS ‘24; BLAST-Obs, BEGINS, POEMM
- SmallSats: TARDIGRADE, InspireSAT, LUVS

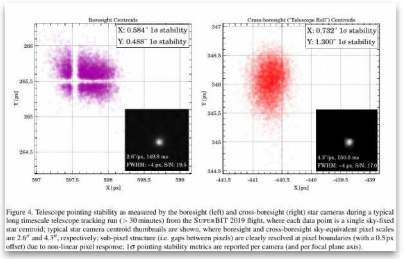


Figure 4. Telescope pointing stability as measured by the boresight (left) and cross-boresight (right) star cameras during a typical long timescale telescope tracking run (> 30 minutes) from the StratoSPEC 2019 flight, where each data point is a single sky-fixed star centroid; typical star camera centroid thumbnails are shown, where boresight and cross-boresight sky-equivalent pixel scales are 2.6” and 4.3”, respectively; sub-pixel structure (i.e. gaps between pixels) are clearly resolved at pixel boundaries (with a 0.5 px offset) due to non-linear pixel response. 1σ pointing stability metrics are reported per camera (and per focal plane axis).

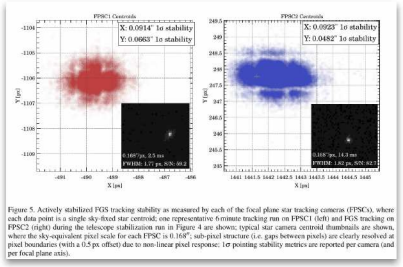
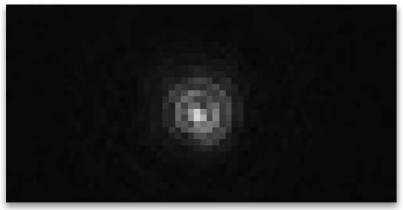
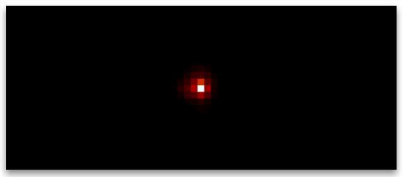


Figure 5. Actively stabilized FGS tracking stability as measured by each of the focal plane star tracking cameras (FPSCs), where each data point is a single sky-fixed star centroid; one representative 6-minute tracking run on FPSC1 (left) and FGS tracking on FPSC2 (right) during the telescope stabilization run in Figure 4 are shown; typical star camera centroid thumbnails are shown, where the sky-equivalent pixel scale for each FPSC is 0.168”; sub-pixel structure (i.e. gaps between pixels) are clearly resolved at pixel boundaries (with a 0.5 px offset) due to non-linear pixel response; 1σ pointing stability metrics are reported per camera (and per focal plane axis).





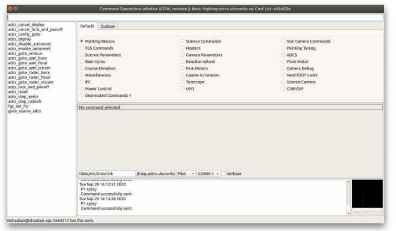
STARSPEC-CMD-TLM

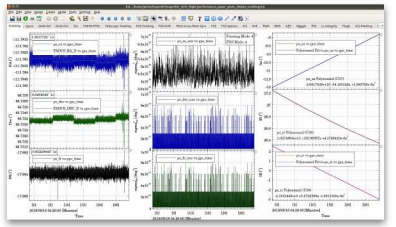
↳General commanding / telemetry API

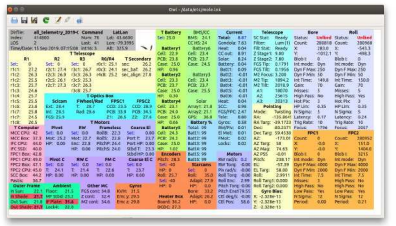
- ↳Standard versatility and functionality
  - Common use-cases for payload command & telemetry from ground to flight to ground
  - Configurable per-payload / per-system
  - On-the-fly telemetry specification
- ↳Robust data handling
  - Redundancy in standard recoverable format
  - Real-time configurable CRC implementation
- ↳High heritage with balloon launch providers
  - Full Compatibility with CSBF and CNES hardware and communication interfaces
  - Standardized API layer over comms hardware
- ↳Ground operator tools
  - Compatibility with open source tools developed by StarSpec
  - API access in C, Rust, Python

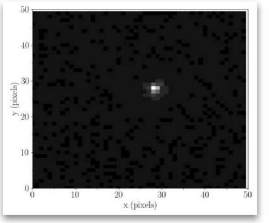
Heritage:
- SuperBIT ‘15, ‘16, ‘17, ‘18, ‘19; BLAST-TNG ‘19

Currently implementing on:
- SuperBIT ‘23; EXCITE ‘23; TAURUS ‘24
- BLAST-Obs, BEGINS, POEMM, SAKHMET
- SmallSats: TARDIGRADE, InspireSAT, LUVS





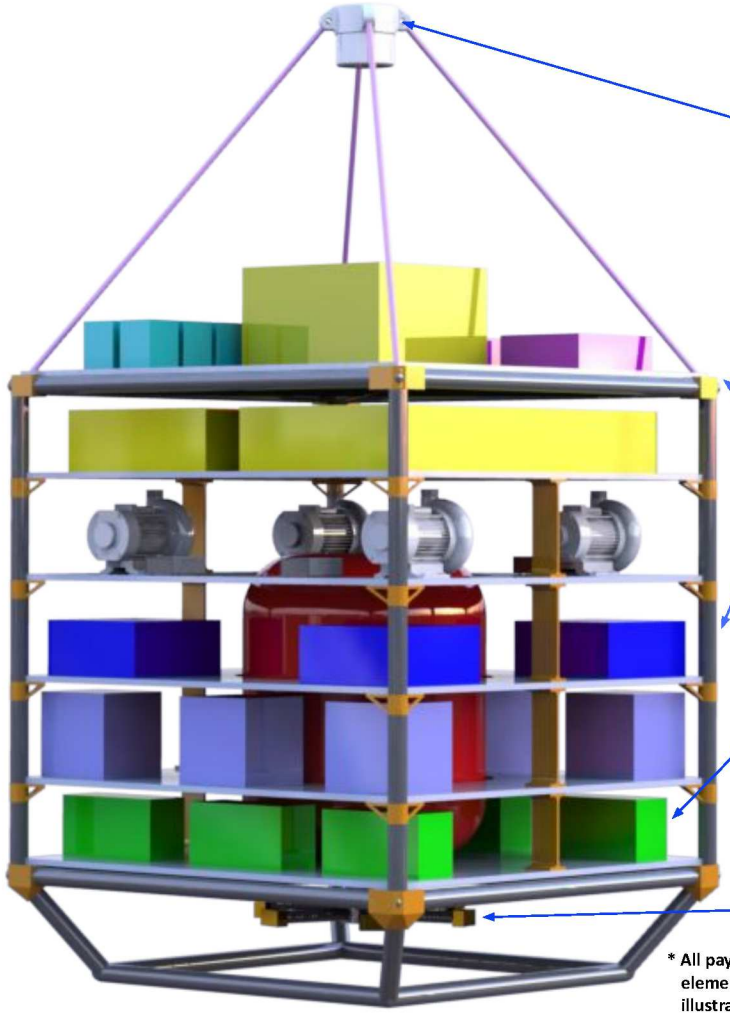




STRATO-SPEC

↳Multi-Payload Gondola

- ↳Large scale technology demonstration
  - Accommodate multiple small (< 10 kg) to large (> 100 kg) payloads
  - Modular gondola assembly
- ↳High power capacity
  - Switched power (20–30 outputs)
  - Support for high current (20 A)
  - Back-emf / inductive-load tolerant
- ↳Az-only control (continuous power generation)
  - Continuous pendulation dampening
  - Post flight reconstruction available
- ↳Component flight heritage, NASA-certified
  - CNES- & CSBF-compatible
  - CNES Generic Gondola



* All payload elements are for illustrative purpose only

StarSpec-Pivot

- CSA / NASA-certified Pivot mechanical balloon interface
- Continuous momentum dump to the balloon via flight train

Modular Frame Design

- Adjustable shelf units (4 m^2 space per shelf)
- Can accommodate numerous test payload form factors
- Accommodations for large cryogenic test payloads

StarSpec-SPS

- 10–20 kWh onboard storage (expandable)
- 1.5 kW solar arrays with coarse Az control (optional)
- 24 VDC switched power available

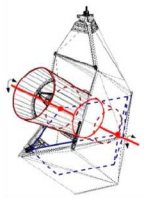
StarSpec-RW (Reaction Wheel)

- Stored angular momentum for pendulation dampening
- Coarse pointing (0.5–1°) and slew (0.5–1 dps) control (optional)

PRECISION-SPEC

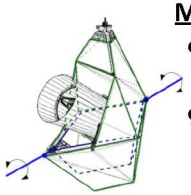
↳Sub-arcsecond Pointed Gondola

- ↳Honeycomb panel structure
  - High modal stiffness
  - Modular design
- ↳Sub-arcsecond, 3-axis stability
  - **0.3" RMS per axis (star-referenced)**
  - 30–90 min. sky-fixed stability
- ↳Milli-arcsecond image stabilization
  - **0.04-0.1" RMS focal plane**
  - High bandwidth stability (50 Hz)
- ↳Flight heritage, CSA- & NASA-certified
  - CSA / CNES- & NASA / CSBF-compatible
  - SuperBIT, EXCITE, BEGINS, POEMM, PICTURE-J, SAKHMET, MOS-DMD



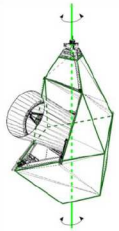
Inner Frame

- Pitch / Elevation control: 20–60° (encoder feedback)
- Dual-stage actuation: slews vs. sub-arcsecond tracking
- Precision sensor suite:
  - **StarSpec-Trackers** for sub-arcsecond feedback
  - Low-noise rate gyroscopes



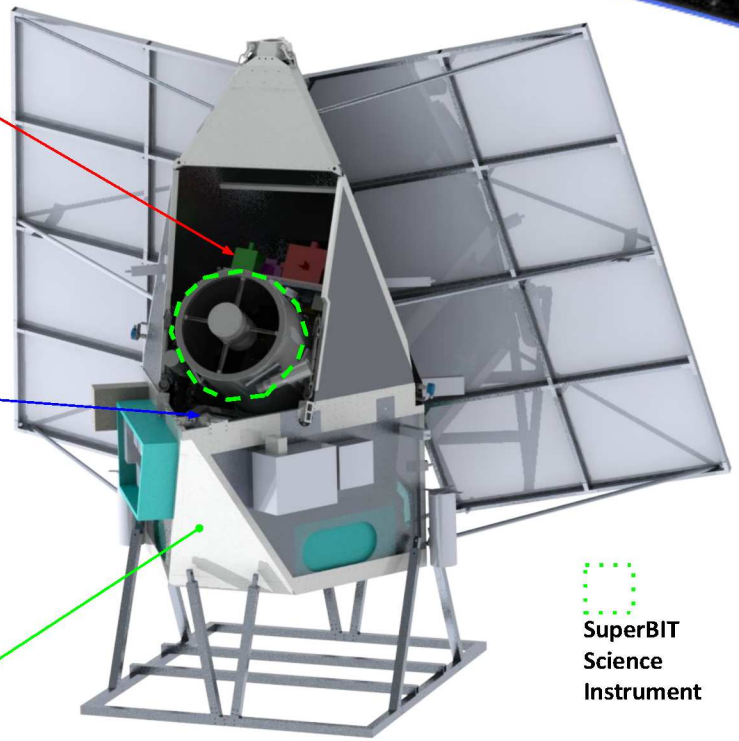
Middle Frame

- Roll control: ±6° (encoder feedback)
- Frame locking system between Inner / Outer Frames for launch, termination, etc.

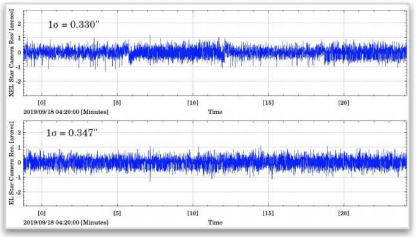


Outer Frame

- Yaw / Azimuth control: 0–360° (sun sensor + magnetometer feedback)
- Active pendulation dampening and momentum dump
- **StarSpec-Pivot** CSA / NASA-certified Pivot mechanical balloon interface
- **StarSpec-SPS**: 8 hrs night ops, 4–8 hrs solar charge



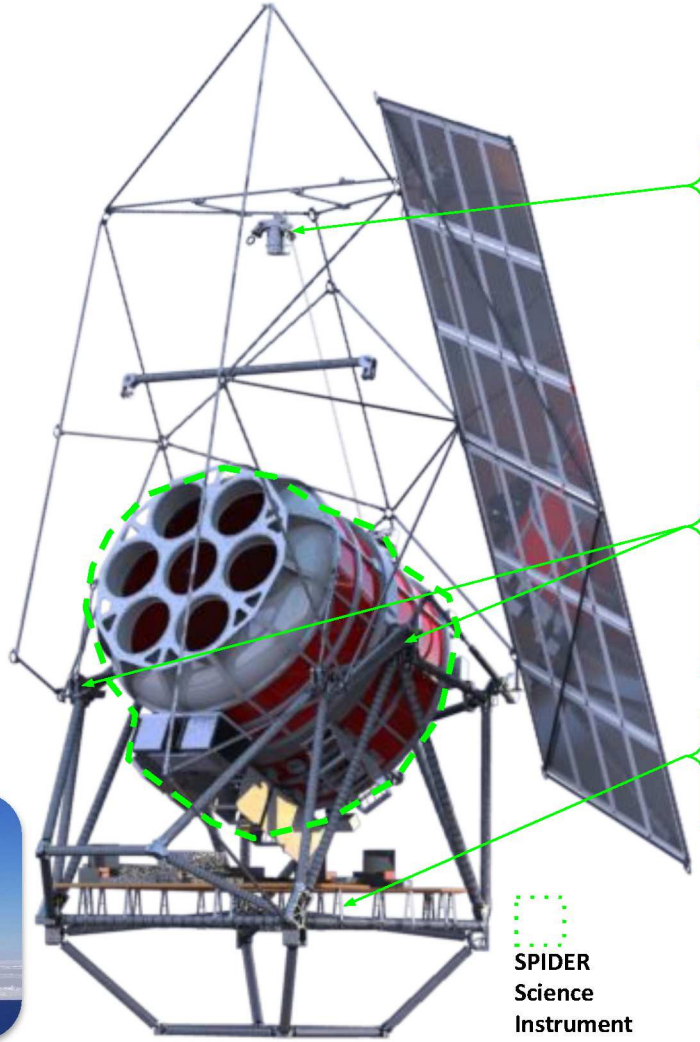
SuperBIT Science Instrument



SCANNER-SPEC

↳High-fidelity Scanning Gondola

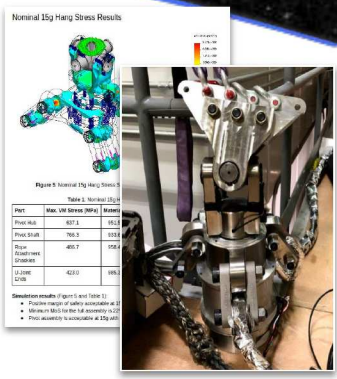
- ↳Composite frame structure
  - Lightweight, high strength
  - Modular disassembly
- ↳Large, high mass payloads
  - Dynamic masses
  - Cryogenic payloads
- ↳Standard Az / El control
  - **Scan speeds: up to 6 dps**
  - **Post-flight: 0.1" reconstruction** from **StarSpec-Trackers**
- ↳Flight heritage, NASA-certified
  - CSBF-compatible
  - TAURUS, Spider2, BLAST-Obs, Spider, POEMM, B-Solitaire



SPIDER Science Instrument

StarSpec-Pivot

- CSA / NASA-certified Pivot mechanical balloon interface
- High-torque motor for slew + continuous momentum dump



Elevation Drive

Two configurations:

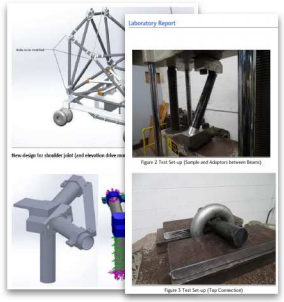
- High precision stepper motor
  - < 1" steps + control
  - Tolerance to payload imbalance
- High torque frameless motor
  - Continuous tracking and control

StarSpec-RW (Reaction Wheel)

- Active pendulation dampening
- > 1000 Nms storage, 20–40 Nm maximum torque

Composite Frame

- Modular design + high strength
- High profile / mass payloads
- High heritage and reliable QA based on 15 years historical data

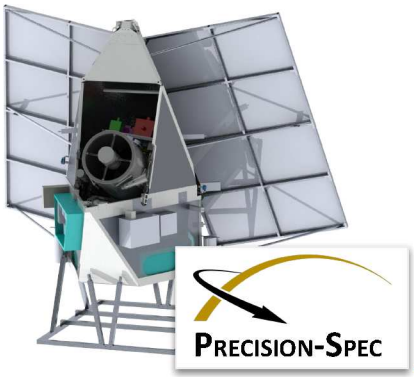


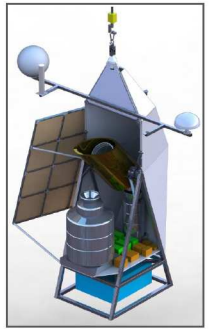
CUSTOM-SPEC

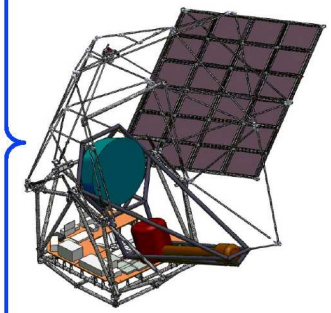
↳Semi-custom Gondolas

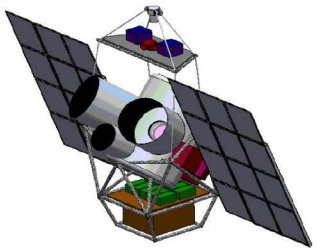
- ↳Heavily leveraged **StarSpec standardized components** in a semi-custom structure
- ↳Hybrid structures for hybrid requirements
  - Combined frame and honeycomb elements
  - Modular disassembly
- ↳Payloads of various sizes accommodated
  - Dynamic masses (up to 500 kg)
  - Cryogenic payloads
- ↳Standard 2- or 3-axis control
  - Pointing stability: < 1″ per axis
  - Scan speeds: up to 3 dps
  - Post-flight: 0.1″ reconstruction
- ↳Maximize mission assurance and versatility
  - Heritage components + select custom elements

Contact Us to Get Started!









DESIGNED-TO-SPEC

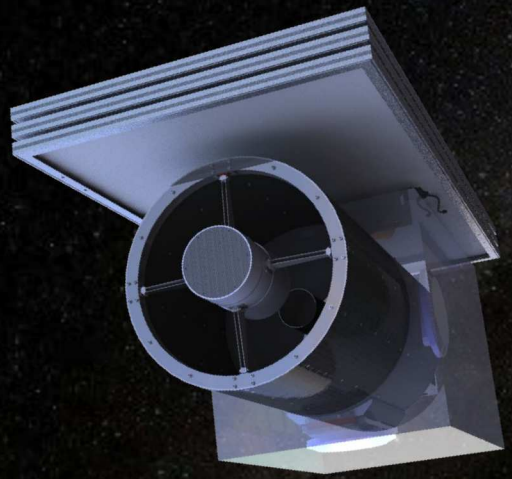
↳Design Studies & Consultation

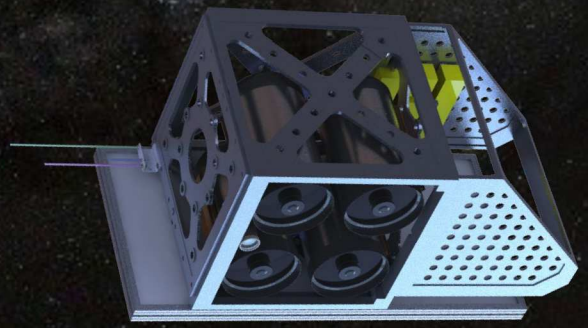
- ↳Entry-level to detailed conceptual designs
  - Up to pre-phase A
  - Requirements formulation
  - Risk identification and mitigation
  - Cost factors and estimation
- ↳Compliance with flight requirements
  - CSBF-NASA and CNES-CSA proposal-level certification
  - Highlight key drivers / limitations
  - Enhanced mission assurance
- ↳High-heritage approach
  - Leveraging decades of successful hardware / software design
  - Global flight data repository
  - Informed semi-custom designs
- ↳Suitable for early-stage funding proposals
  - Rendered graphics (inc. payload)
  - Team collaboration & engagement
  - Gondola proposal text available

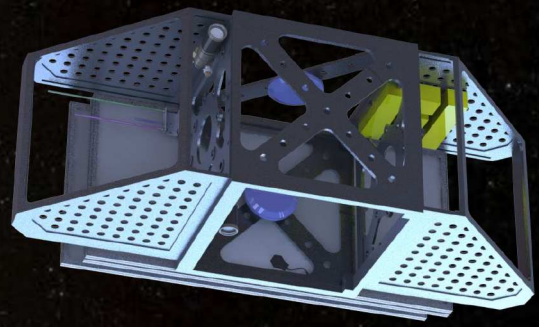
Contact Us to Get Started!

StarSpec in Orbit!

Standardized **Plug-and-Play** SmallSats & Components







STM
Space Telescope Module

EOM
Earth Observation Module

SCM
Space Certification Module

The Hubble Space Telescope

HIGH-RES PERFORMANCE

2–3 days / mosaic

STARSPEC

HIGH-RES PERFORMANCE

17 min. / full image

Motivation

Trends in Ballooning

- **Institutional focus and deep Science interest in SPB capabilities**
  - Longer flights, day-night & mid-latitude access
  - But, technology uncertainties / unknowns
    - Mass constraints, robust day-night power / thermal management, higher longevity requirements, data downlink, etc.
- **The *Decadal Survey on Astronomy and Astrophysics 2020***
  - Standardization in components essential for success.
  - **"Less custom, more COTS!"**
    - Can suborbital programs provide technology value-adds?

BLAST-TNG payload—Antarctica 2020

SpaceX Launch—April 26, 2022

Trends in *New Space*

- **Privatization of launch, infrastructure, and services**
  - Emerging demand for at-scale and economy-of-scale
  - New industries want or assume a low barrier-to-entry
  - Mega-constellations to support space-based infrastructure
- **"Less custom, more COTS!"**
  - Demand for end-to-end solutions that "just work" at scale
  - Can consumer-level COTS be leveraged for space?
    - **StarSpec has shown that the answer is "Yes!"**

Technology Approach: *Standardization*

Enhanced Mission Assurance

- **Leverage a wealth of expertise and heritage**
  - No need to "reinvent the wheel"—many supporting capabilities are solved problems for which solutions are well established
- **Foster fundamental research and innovation in technology**
  - Pedagogy remains an important aspect—we aim to enable a refocusing towards the "interesting problems" with support and training in well established supporting capabilities
  - **Thesis**: enabling higher success in gondola and bus functionality increase chances that both new research and innovation are achieved

SuperBIT Inner Frame components and subsystems—Timmins 2019

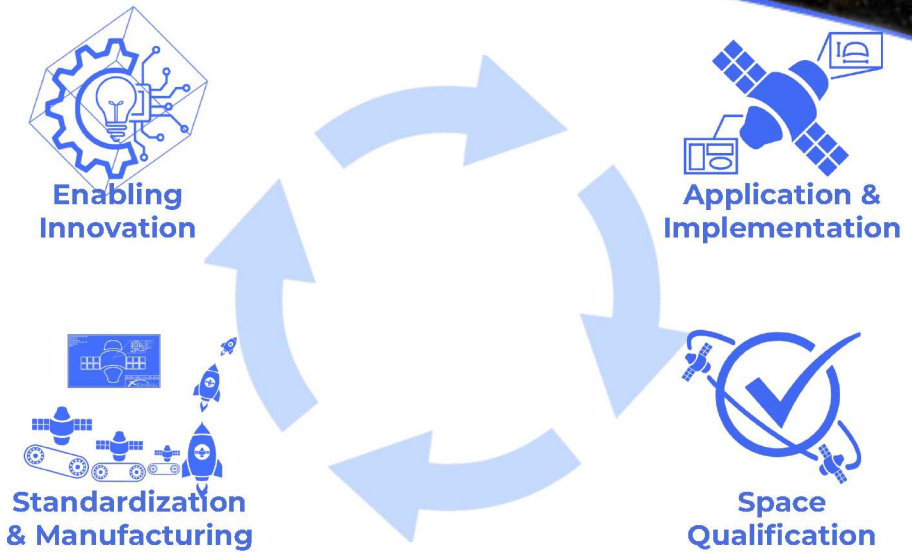
Bottoms-up Approach

- **Massive leg-up from ballooning experience and heritage**
  - Quick turnaround in technologies, keeping pace with consumer-level COTS
  - Realize targeted value-add from technologies developed on balloon-borne gondolas for space-based applications
- **Start small, demonstrate value, build on it**
  - Component-level -> subsystem-level -> bus-/gondola-level
  - **Goal:** fully plug-and-play systems that "Just Work"

Moving Forward

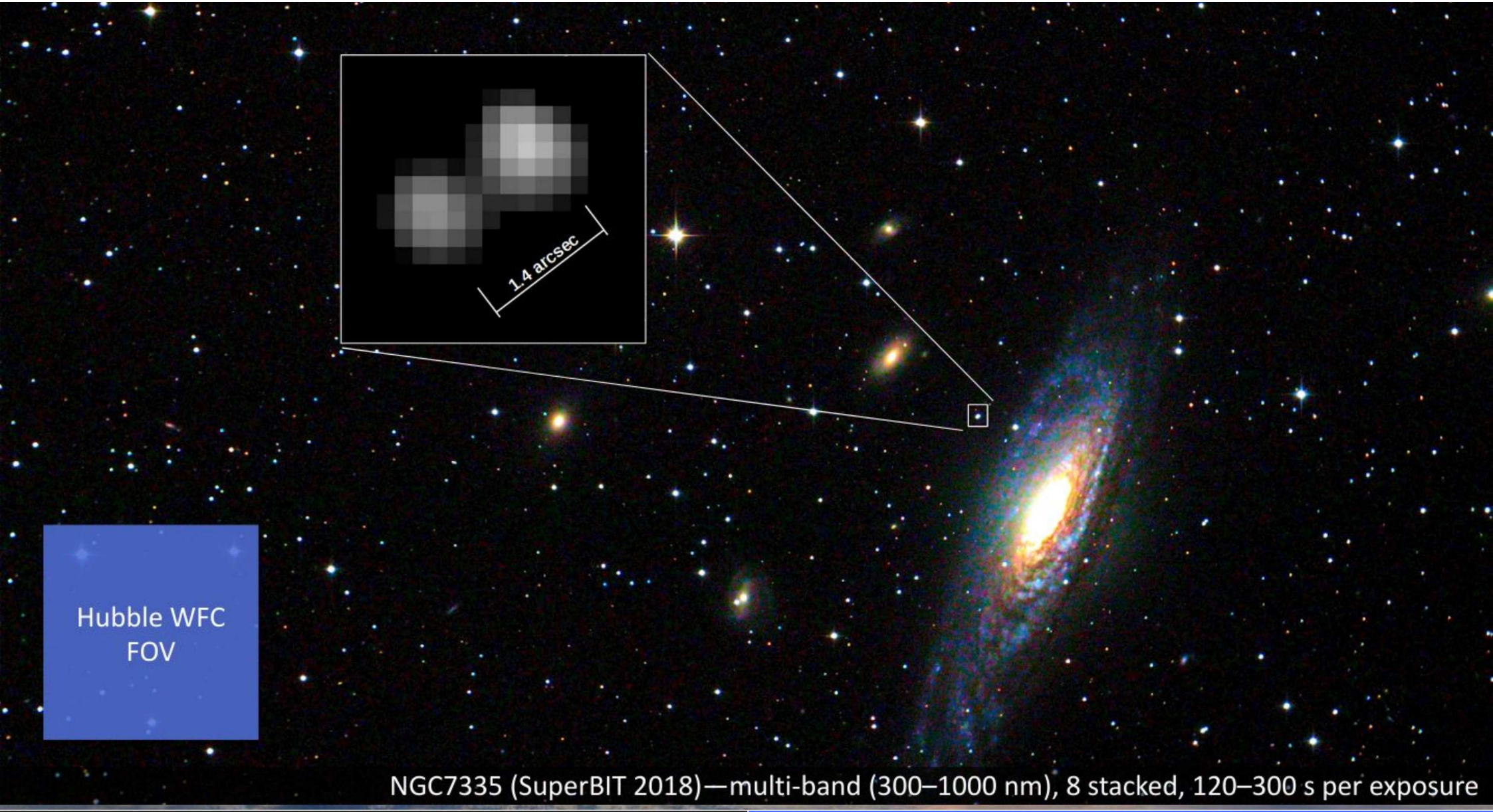
Engagement with Major Players & Future Leaders

- **Well-established industry leaders**
  - Seeking institutional partnerships for technology development and implementation—lower the barrier-to-entry for space
  - Success in direct engagement as well as through the NASA POD process
- **Up-and-coming *New Space* leaders**
  - Academic institutions across the US and Canada; new PIs and future technology leaders looking to utilize space
  - We are working with private launch providers (SpaceX, aggregators, etc.) to develop scalable plug-and-play components / buses



Further Technology Development

- **Keeping pace with consumer-level COTS**
  - **Secret sauce**: the ability and versatility to take ground-based consumer-level COTS and rapidly qualify for space
- **StarSpec is taking on the burden of standardization**
  - We are uniquely equipped to move quickly with the technologies & heritage-backed methodologies in hand
  - **StarSpec vision:** to be a key enabling layer for next-generation at-scale space-based applications



NGC7335 (SuperBIT 2018)—multi-band (300–1000 nm), 8 stacked, 120–300 s per exposure

The Omega Nebula (SuperBIT 2018)—multi-band (300–1000 nm), 8 stacked, 120–300 s per exposure

StarSpec Additional References

- Balloon-borne Sub-arcsecond Stabilization
- SuperBIT 2019 performance paper
- Balloon-borne Structural and Modal Analysis
- Balloon-borne Scanning / Stabilization Control