

Interstellar Boundary Explorer (IBEX) Lessons Learned

Presented for the Astro Explorers Forum

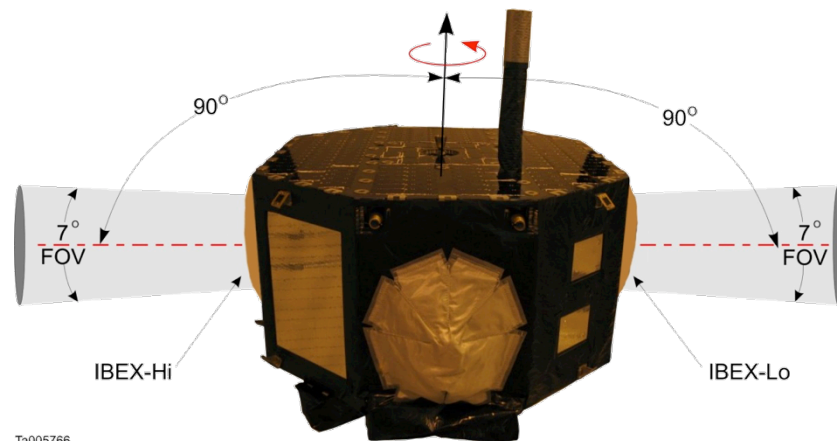
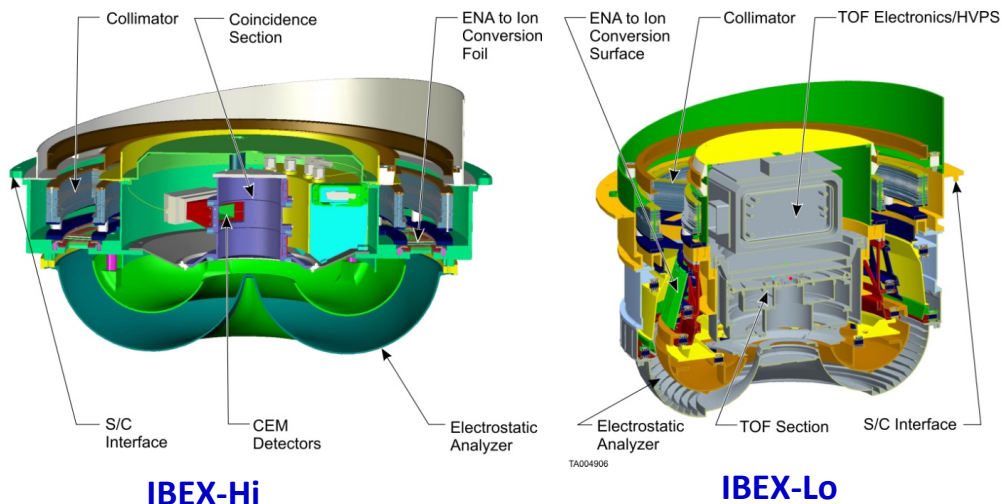
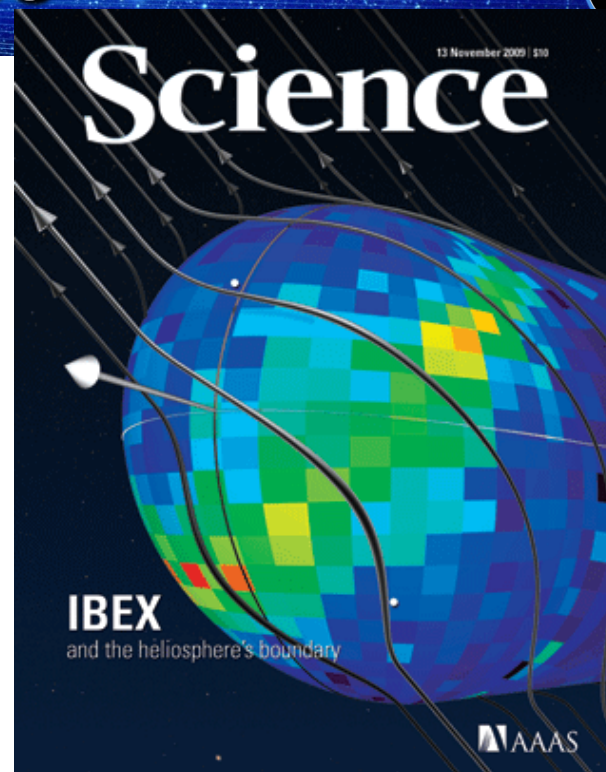
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IBEX Overview: Science

- Designed to map the entire region of the boundary of our Solar System and discover the global interaction between the solar wind and the interstellar medium.
- Takes global energetic neutral atom (ENA) images from the outer heliosphere.
 - IBEX-Lo (0.01-2 keV)
 - IBEX-Hi (0.3-6 keV)



Team

- **SwRI:** PI, PM, MSE, P/L Electronics
- **LANL:** IBEX-Hi
- **LMATC:** IBEX-Lo
- **UNH:** P/L Collimators
- **Orbital:** Spacecraft, MOC

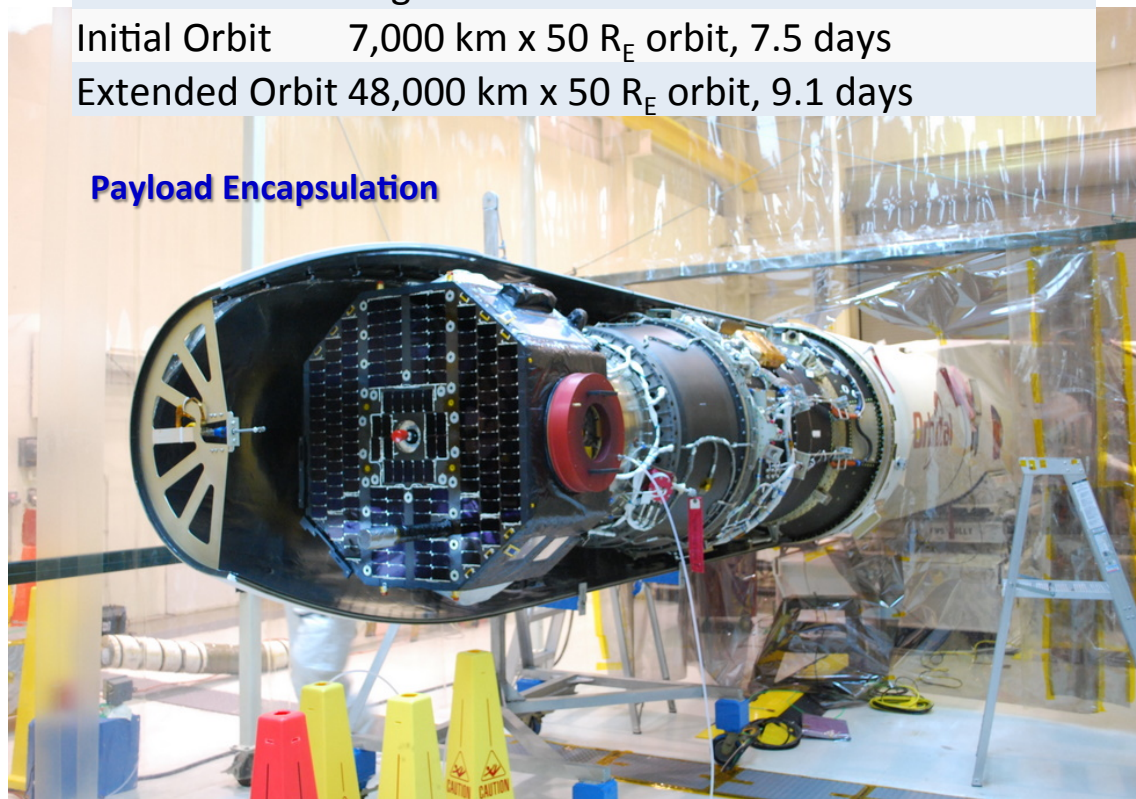
Timeline

- **2003:** Step 1 Proposal Submitted
- **2004:** CSR Submitted
- **2005:** Awarded \$103M (does not include GFE LV)
- **2008:** Launched
- **2011:** 1st Extended Mission
- **2014:** 2nd Extended Mission

Mission Details

Launch Mass	460 kg (including 271 kg SRM propellant and 26 kg hydrazine)
Payload mass	26 kg (57 lb)
Power	66 W (116 W max)
Launch Vehicle	Pegasus XL
Initial Orbit	7,000 km x 50 R _E orbit, 7.5 days
Extended Orbit	48,000 km x 50 R _E orbit, 9.1 days

Payload Encapsulation





Lessons Learned

After submitting CSR and selection, SR&QA requirements increased:
~20 pages of requirements with “should” became 100+ with “shalls”.

The Fix

- IBEX was selected at the time that the new MAR was being invoked.
- After discussions, the new requirements were considered a change of scope.
- IBEX prepared impact proposals and let Explorer’s choose á la carte what requirements to invoke; these were ultimately included in the contract.

In Hindsight

- In the CSR be as explicit as possible about your assumptions of what is really required.
 - CSR is the time to do this because that is what the project signs up to and NASA selects.
- In general, you must expect changes and roll with them; Explorers and IBEX worked together to find a solution.
- Changes should be expected over the life of the project.

The originally proposed transceiver was not a transponder and did not allow for ranging. Original method of orbit determination did not meet spec.

The Fix

- We upgraded the transceiver to be a transponder.
- Complications:
 - Foreign vendor
 - More expensive
 - Became mission schedule critical path (and thus more management time and cost)
 - Increased complications in S/C I&T
- In the end, new transceiver was delivered on time and has been working on orbit for 8 years.

In Hindsight

- Get (early) independent insight into all critical analyses.
- Original IBEX team was not strong in orbit dynamics.
 - Independent group (FDG) who does orbit determination every day should have been part of the team from day one.
- Side benefit: FDG later came up with Lunar Synchronous orbit for extended mission.

Parts were an issue from day one: use of plastic parts, radiation approval, late delivery of parts, etc.

The Fix

- There really wasn't one (and parts have been an issue on my two projects after IBEX).
- Parts were a driver until I&T and beyond.
- Parts management was a huge drain on funds.

In Hindsight

- We should have put more attention on parts management (and we did put a lot on it from day one).
 - CSR even included parts plan for plastic parts.
- Not sure this can ever NOT be an issue.
 - Late delivery
 - Late GIDEP, etc.
 - A lot of this is outside project's control.

IBEX was extremely mass constrained. Prior to selection, the IBEX concept utilized 3 Motorized Light Bands (MLBs), a new technology with limited flight heritage and analysis, which used commercial motors.

The Fix

- In the eyes of the review panel, the MLBs were an issue from day one (rightfully).
- MLB fab, test program and implementation were scrutinized by IBEX, review team, and GSFC subject matter experts.
 - This lasted all the way through mission PSR (residual risk at launch).

In Hindsight

- MLBs provided large mass savings over standard V-bands, but IBEX ended up flying ballast and ultimately did not need this efficiency.
- If we had known flight segment mass and real LV performance earlier, we probably could have used conventional sep systems.
- Answer was probably to start MLBs and test qual model earlier.

LV Loads identified as a risk as early as SRR due to change in igniters on the Pegasus stage 2 motor. At “final” Coupled Loads Analysis, LV loads ended up higher than designed to.

The Fix

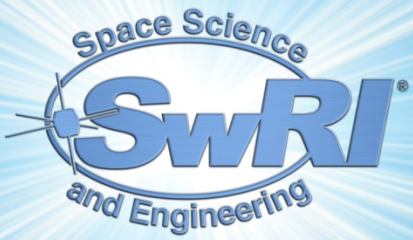
- Ultimate fix was to delay launch by 3 months and install a Shockring.
- PSR was held knowing that IBEX had a loads problem.
- CSA was turned on, and the tested isolation system was delivered in ~3 months.

In Hindsight

- Not really sure what else could have been done other than including Shockring from day 1 (might have been cheaper in the long run).
- Things done include:
 - Hired Orbital to build S/C launched on Orbital rocket.
 - Built SRM qual model for test firing; it was then cleaned and loaded with inert fuel for dynamics testing.
 - Tested S/C, flight segment, etc. as soon as possible.

- Certified Earned Value Management (EVM) now required.
 - IBEX did EVM but level of rigor, documentation, etc. that is currently required is a huge increase in scope.
 - Don't underestimate this effort: On CYGNSS (project of comparable scope and schedule) we have ~2 FTEs for schedule and financial reporting, and that is probably not enough.
- IT Security requirements have greatly increased, which significantly impacted IBEX Phase E/Extended mission funding needs.
 - Due to increased vulnerabilities and intrusions, IT Security spending is much greater than planned, AND requirements are continually changing and increasing in scope.

- Reserves: Dollars and schedule should not be allocated to subsystems upfront; PI/PM should control and jealously guard them.
- Scope: Likewise, this is not the time for “it sure would be nice if” – fight against any new / increased scope.
 - Guaranteed, you will have enough issues that new scope is not needed.
- Word to PMs: Explorers Mission Manager is your closest ally.
 - Mission Manager will help diffuse and buffer you from NASA high-gain, undamped system.
 - Key is to keep Mission Manager in the loop with no surprises.



Good Luck!