Aeronomy of Ice in the Mesosphere (AIM)

Lessons Learned

James M. Russell III - AIM PI
Hampton University, Hampton, VA

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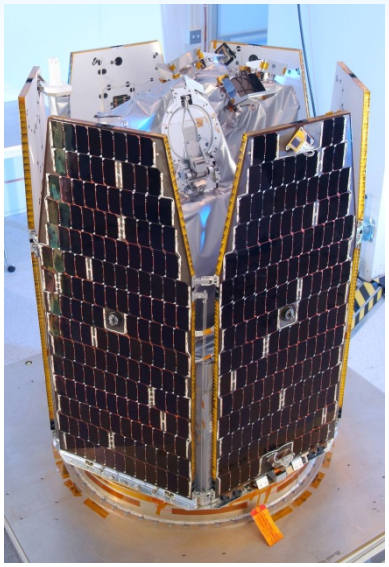
Aeronomy of Ice in the Mesosphere (AIM)

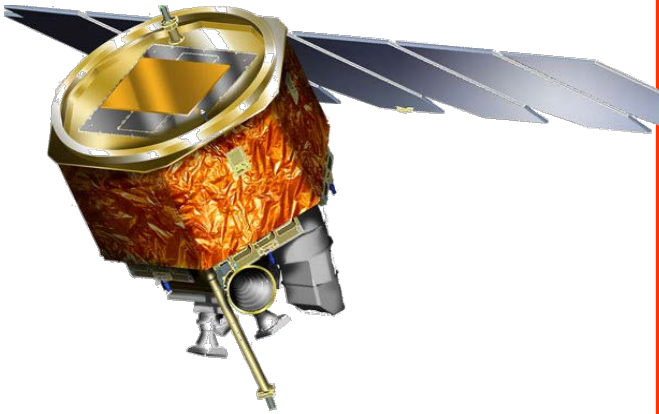
- **Science Goal: Why do noctilucent clouds form and vary?**

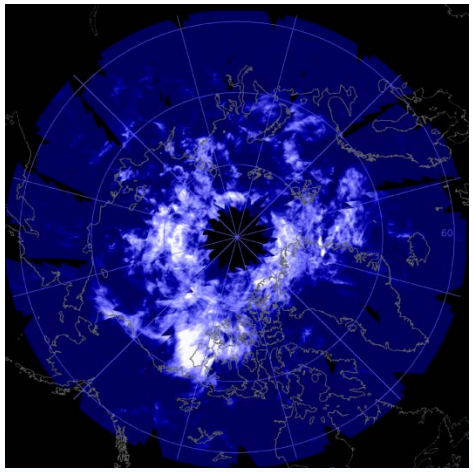
- **Three instruments**
  - Solar Occultation For Ice Exp (SOFIE)
  - Cloud Imaging and Particle Size (CIPS)
  - Cosmic Dust Experiment (CDE)

- **Cost Cap – $104M**
- **April 25, 2007 launch**
- **SOFIE – USU/SDL**
- **CIPS and CDE – CU/LASP**
- **Spacecraft – Orbital ATK**
- **197 kg, 243 W observatory**
- **3 m x 1.5 m x 1.3 m**

AIM was launched from VAFB by a Pegasus XL rocket







NH cloud on July 10, 2014

- Near perfect 600 km circular orbit (± 2 km)
- Observatory is working well; excellent data being returned; 25 PMC seasons observed
- New insights about NLCs developed (>300 pub)
- Shows long-term PMC change at ~ 83km
- Mission approved to go through 2020

AIM ruling principles for managing partners

- **We are all part of one team**
  - HU, LASP, SDL, Orbital ATK - S/C and LV
  - AIM Science Team
  - NASA HQ, Explorer's Office, KSC launch team
  - One for all and all for one
- **PI solved development problems with the help of an AIM Executive Advisory Council**
  - Director of LASP, Director of SDL, Orbital ATK VP for the Space Systems Group and Launch Services Group
  - Met by telecon as needed, once or twice a year

Lessons Learned
From the selection Debrief

AIM SOMA Selection Debrief

- TMC panel expressed serious skepticism about cost and schedule
- NASA will not confirm unless mission is within cost cap
- Inadequate funded schedule reserve
- Other Concerns
  - Low mass margin
  - SOFIE instrument immaturity
  - RS300 spacecraft immaturity
- The TMC panel noted that there was room to descope

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At this point, science and cost became of similar importance

**“I find that the harder I work,
the more luck I seem to have.”**

Thomas Jefferson

Timeline of major AIM actions taken after selection debrief

CSR	Change	Action Date	Risk Reduction
SOFIE mass 50kg	Streamlined design, better science; - 12 kg	March 15	Mass
First build spacecraft	5th generation spacecraft	June 3	Cost, mass
Four science instruments	SHIMMER removed, science impact	June 6	Cost, mass, data volume
Instrument Platform Assembly (IPA)	Removed	June 15	Cost, mass
New LV contract	Use existing contract	June 19	Cost
CDE new development	Use New Horizons SDC copy	July 25	Cost, schedule
Six CIPS cameras	Four cameras, small science impact	August 1	Cost, mass, data volume

Timeline of major AIM actions taken after selection debrief

CSR	Change	Action Date	Risk Reduction
Use Pegasus HAPS to trim orbit	Remove HAPS	February	Cost
Total overall estimated resource savings		$ 10.7 M 61 kg	-----

Lessons Learned
During the AIM development

“In the field of observation, chance favors only the prepared mind.”

Louis Pasteur

Major AIM lesson learned – Work the options and be prepared

- Pursued Minotaur launch vehicle for ~ a year; would have provided potentially significant cost savings
- Performed detailed feasibility study for flying AIM instruments on existing VCL bus and worked with NASA HQ from late Oct., 2002 until Mar. 2003 trying to secure the VCL bus
- Replaced baseline gyro in Phase B with a more expensive but more reliable and capable unit
- Dealt with changing launch loads from end of Phase B to launch
- Replaced SOFIE steering mirror with a rigid mirror in July 2006 after a major observatory vibration event

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- **Changing Pegasus load environments caused significant adjustments to observatory load requirements from ~ Nov 2004 to launch**

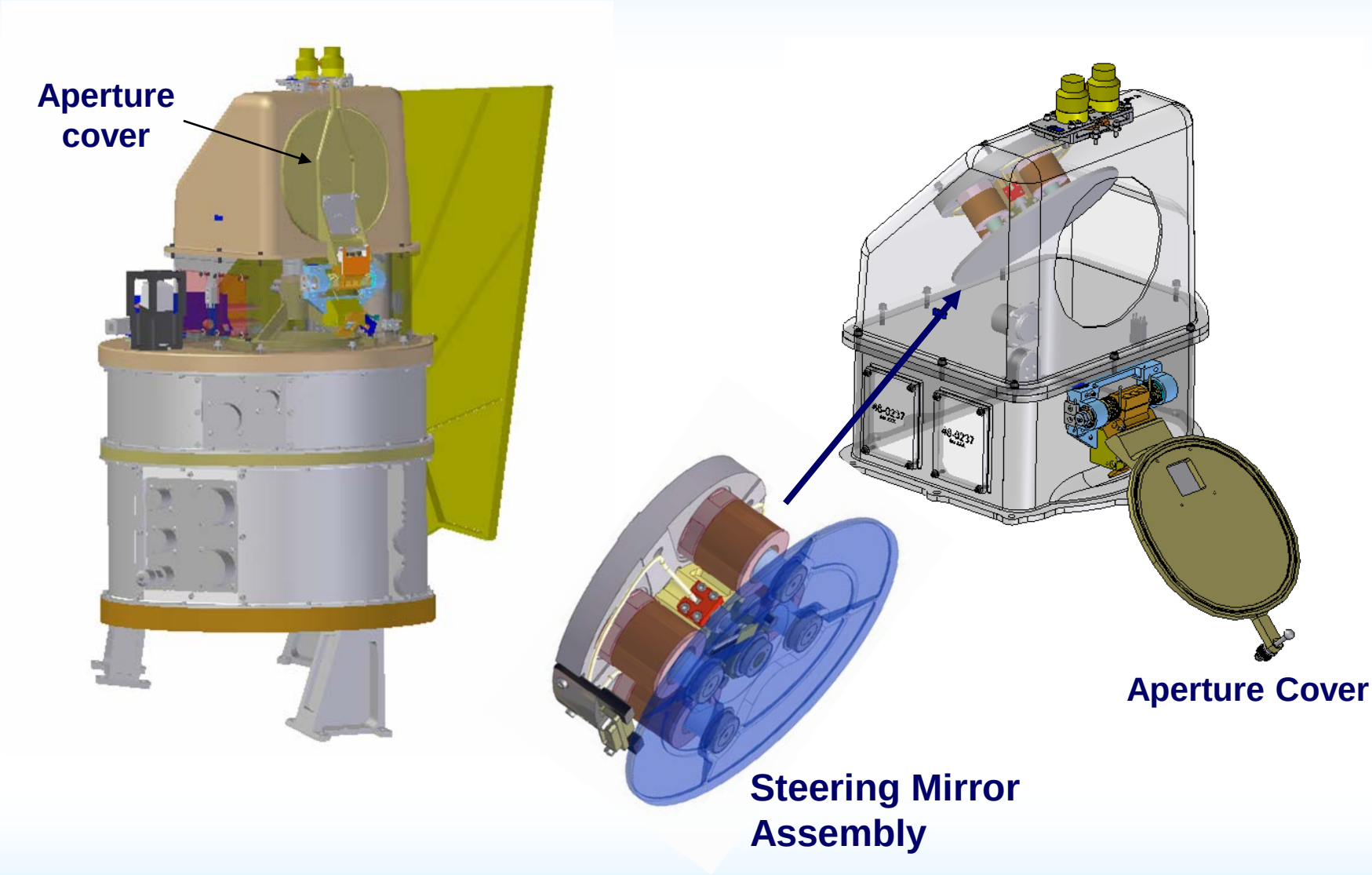
Be prepared to deal with evolving requirements that are beyond your control

SOFIE Steering Mirror Assembly position sensor broke during observatory vibration

- Replaced SOFIE steering mirror with a rigid mirror in July 2006
  - spacecraft used to do the sun pointing

Be prepared with carefully considered backup or descope plans in the event of unforeseen major issues

SOFIE instrument showing the Steering Mirror Assembly



Four SOFIE Steering Mirror options existed to deal with the broken assembly

- Repair the flight Steering Mirror Assembly (SMA)
- Replace the flight SMA with a redesigned system
- Implement a caging mechanism for the SMA
- Replace the SMA with a rigid mirror mount and rely on the spacecraft for pointing

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Launch actually occurred only 10 months after this anomaly!

Lessons learned in the AIM development

- Recognize the wisdom and advice of the TMC panel
- Place high importance on cost as well as science
- Develop a very thorough knowledge of requirements and hold them sacrosanct
- Anticipate problems before they occur
- Plan backup approaches and work arounds
- Engage the entire team in problem solving
- Involve the Executive Advisory Council in critical matters
- Make timely decisions
- Never lose sight of the mission science goal

Backup Slides

An alternative to the SMA was in place as a backup approach

- Concern existed about the SMA actuator bonds to the back side of the mirror surface
- A “ghost” SMA was built by the vendor to allow more in-depth evaluation of the strength of the bond
- A rigid mirror backup approach with the spacecraft doing the SOFIE pointing was evaluated
- A rigid mirror was purchased, integrated and tested early in the SOFIE development in anticipation of problems
- Detailed science analyses were conducted and a rigid mirror approach was considered acceptable although not ideal

AIM S/C event history (Aug 2002 to June 2003)

- PI requested Ball VP to conduct a detailed RS300 bus cost review in Sept., 2002. Other cost reviews occurred later in the development.
- Started investigating spacecraft options in late Oct. 2002 and continued to work with Ball to seek resolution
- AIM funded OSC to do a detailed feasibility study for flying AIM alone on the VCL bus and LEOStar bus with positive results in May 2003
- Worked with NASA HQ from late Oct., 2002 until Mar. 2003 trying to secure the VCL bus
- Code Y would not commit to providing VCL bus to AIM mission
- RS300 cost review May 23, 2003
- RFP briefing from Orbital for a “SORCE like” spacecraft in June 2003

Changed spacecraft vendor in June 2003

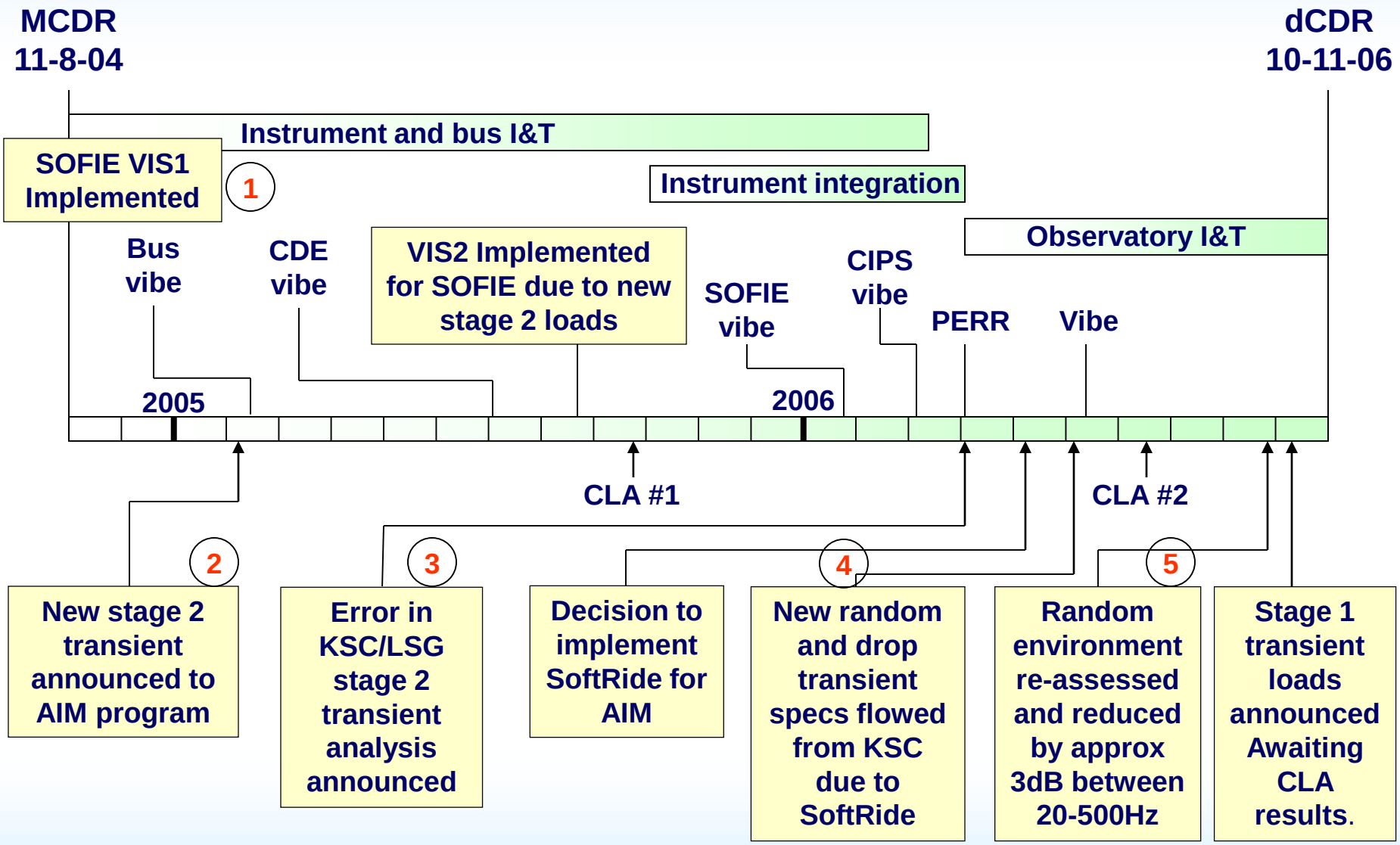
Significant Risk Reduction: Medium to high risk missions unlikely to be confirmed – use heritage hardware where possible.

Mission Assurance Plan Changes

- **Columbia Accident Investigation Board (CAIB) recommendations led to a change in Mission Assurance Plan Requirements**
  - **Came after long lead parts procurements on spacecraft**
  - **Involved significant discussion and review at highest levels of NASA just prior to shipment to the launch site**
  - **Held up observatory shipment for several days**
- **It is critical that EEE Parts requirements agreements be made in writing early to avoid ambiguities and problems late in the development**

Be prepared to deal with evolving requirements

AIM Loads Environment History



The AIM team had to cope with an extremely large number of reviews

Be prepared to deal with evolving requirements from NASA

Reviews and Oversight

Reviews Beginning May 21, 2003

IIRT Plan 4/1/03

Systems Requirements Review
MPDR / Confirmation Assessment Review
Confirmation Readiness Review
Critical Design Review
Pre-Environmental Review
Pre-Shipment Review
Operations Readiness Review
Mission Readiness Review
Launch Readiness Review
Flight Readiness Review

- **3 planned reviews grew to 29**

SRR		21-May
CIPS & CDE Cost Peer Review	WebEx	15-Jul
SOFIE Cost Peer Review	WebEx	16-Jul
WBS Cost Peer Review	WebEx,	17-Jul
SOFIE Δ Cost Peer Review	Webex	18-Jul
Orbital S/C Cost Peer Review	WebEx	21-Jul
Δ SRR	OSC	21-Jul
AIM Project Cost Peer Review	WebEx	6-Aug
CCSRR Peer Review	Webex	6-Aug
CCSRR	LASP	14-Aug
S/C Peer Reviews	Orbital	Oct
S/C PDR	Orbital	20-Oct
SOFIE Peer Reviews	SDL	Oct
SOFIE PDR	SDL	22-Oct
CIPS & CDE Peer Review	LASP	23-Oct
SOFIE DPDR Action Planning Meeting	SDL	28-Oct
CIPS/CDE PDR	LASP	6-Dec
Judson Detector Fact Finding	Judson	10-Dec
Bus Thermal Peer Review	Orbital	11-Dec
SOFIE Peer Reviews	SDL	13-Dec
SOFIE PDR	SDL	13-Jan
S/C Structure Peer Review	Orbital	20-Jan
Mission PDR	LASP	27-Jan
Confirmation Assessment Review	LASP	28-29 Jan
SOFIE Action Plan Assessments	SDL	Feb
Schedule Peer Reviews -- Staff and IIRT	Webex	4-Mar
Steering Mirror Peer Review	SSG	15-17-Mar
Confirmation Readiness Review	GSFC	19-Mar
AIM Confirmation Review	NASA HQ	28-Apr

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- **3 planned reviews grew to 29**
- **50+ Reviews from 5/03 SRR to 11/04 MCDR Including 3 SRRs and 2 SOFIE PDRs**

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