Lessons from AIRES for SOFIA Instrument Proposals

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INTRODUCTION

AIRES, the Airborne Infrared Echelle Spectrometer, was the highest rated of 19 U.S. science instruments proposed for SOFIA in 1997. The instrument is described in the poster below this one. AIRES was cancelled in 2001 due to "cost problems". Can proposals for second generation instruments benefit from the AIRES experience?

To understand the lessons, refer to AIRES' history below.

LESSONS, keyed to red numbers in history

For instrument proposers:

A. (2): Include an experienced project manager in preparing the proposal.

B. (3): Document costs of comparably complex instruments for ground-based telescopes. Relate these costs to the estimated cost in your proposal.

C. (6): Provide realistic assessments of technology readiness levels (TRLs) and corresponding estimates of cost and schedule.

For SOFIA managers:

D. (1, 4, 14, 16): SOFIA needs an AIRES-like **facility** spectrometer.

E. (5): Judge proposals on cost realism, as well as scientific potential and technology readiness.

F. (7): Simplify and provide well-defined guidelines for airworthiness approval.

G. (8): Be realistic in setting schedule deadlines for instrument development.

LESSONS (2)

H. (9, 10): Anticipate, budget, protect, and consistently provide funding for science-instrument development; fence instrument funding, so that it will not be raided to solve problems with the observatory.

I. (11): Require quantitative institutional commitments - *e.g.* contracts - for supporting instrument developments.

J. (13): Establish and provide criteria for instrument reviews well in advance, and do not change them at the last minute.

K. (3,12): Document and distribute to proposers the actual costs, including institutional contributions, for the first-generation SOFIA science instruments.

J. (17): Respond formally to serious requests for proposed programmatic opportunities.

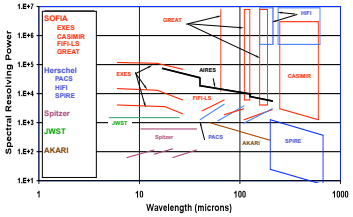
L. (General): Collect, digest and distribute lessons from all existing SOFIA instrument teams.

COMMENTS

The dominant factor leading to AIRES demise was the team's original underestimate of the effort required, and its corresponding cost (3). Major contributing factors were the lack of a dedicated, experienced manager during the proposal preparation and beyond (2), and the increasing cost of civil-service labor during the development (12). Other factors were schedule (8) and airworthiness compliance (7) requirements and SOFIA politics (9, 18). However, it is likely that few of the SOFIA instruments would have survived literal interpretation of the second and third cancellation review criteria above (13).

The AIRES-team had met its unique technical challenges, depicted in the figures at right (6, 15). In addition, the team had accomplished much on all aspects of the development.[2] AIRES' termination was a serious loss for SOFIA, as cited above (1, 4, 14, 16), and as the adjacent plot reveals.

Mid-, Far-IR and Submm Spectrometers

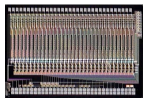


AIRES' performance would be unique relative to recent and future space spectrometers.

Cryogenic Multiplexer for FIR Photoconductor Detectors

The SBRC 190, a 1x32 format integrated circuit, was developed and tested by the AIRES team. Properties:
- operating temperature as low as 1.5 K
- selectable well capacities
- moderate backgrounds
- rapid sampling synchronized with chopper enables detector BLIP in AIRES on SOFIA

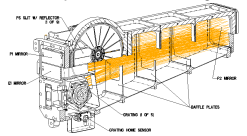
size 4x6x0.5 mm



World's Largest Monolithic Grating

Bernard Bach machined the AIRES grating. Diffraction-limited at 4 μm, it's nearly 4x better than the requirement.

Optical and Mechanical Design



This subsystem sorts echelle orders. 100% of the optical design and ~80% of fabrication drawings were completed.

HISTORY (1)

1. **The1990 National Academy of Sciences Decadal Survey ("Bahcall") Report, which recommended the development of SOFIA, cited "SOFIA's Most Important Attributes:**

High-resolution spectroscopy at wavelengths > 30 µm

2.5(wavelength/30 µm) arcsec imaging at wavelength > 30 µm

Training of instrumentalists"

A team at NASA Ames, with collaborators from other institutions, had developed the far-infrared Cryogenic Grating Spectrometer (CGS), and used it to make successful observations from the KAO every year from 1982 until it was retired in 1995. By 1994, the Ames group had made serious plans to propose **AIRES - a facility science instrument - for SOFIA[1].**

AIRES would be a long-slit spectrograph with a mid-infrared slit-viewing imager. It would use three 2-dimensional detector arrays to provide imaging along a 3 arc minute slit at wavelengths from 17 to 210 microns. This is the same wavelength range of its predecessor, the CGS.

In planning AIRES, an experienced project manager (PM) was tentatively assigned from the Ames Space Projects Division. 2. However, when the proposal was being written, she and no other Ames project manager were available to assist with the proposal, so it was written without one. The Principal Investigator (PI) took on that role. Just before the proposal was submitted in July 1997, a business manager was assigned to join the team if the proposal would be accepted.

HISTORY (2)

The effort proposed, based on experience with the development of the CGS, was estimated to be 40 full-time equivalent work years (FTE). Over half of this consisted of identified, experienced Ames civil-service scientific and technical personnel..

3. The AIRES team made no effort to obtain cost estimates of other comparable, contemporary spectrometers developed or being developed for ground-based observatories, so that both effort and cost were badly under estimated. Much later, costs of such instruments were found to be two to three times higher than the proposed AIRES estimate.

4. **The AIRES proposal, submitted 15 July 1997, was judged by peer review to be the highest priority for SOFIA among 19 proposals submitted.** 5. The primary review criteria were scientific potential and technical feasibility. The proposal submission was approved by the Ames Space Sciences Directorate management. Development began in October that year. 6. Long lead-time, higher-technology items received priority as described in the proposal, but progress was slower than anticipated. 7. Also, labor costs were increasing nonlinearly because charges for Ames civil servant labor were rising rapidly under the implementation of full-cost accounting in NASA. Unanticipated expense from the requirements for FAA approval added to a projected overrun and delay. By mid FY98 the team apprised Ames management that the original estimate of effort was inadequate. They agreed to help financially on the condition that they assign a PM to run the project in place of the PI.

HISTORY (3)

Their thinking was that the project was badly managed, rather than primarily having been underestimated initially. 8. The new AIRES PM added staff and procedures which further increased the cost, in an attempt to meet a completion deadline (~2004), requested by USRA, that proved to be completely unrealistic.

In mid-2000, the SOFIA project was experiencing "cash-flow" problems. The AIRES team had selected a contractor from several bids to build its cryostat according to the design it had completed. 9. The NASA Program Manager and USRA Chief Scientist requested the AIRES team to defer signing the contract until the next fiscal year, so that the AIRES money could be transferred to help solve the SOFIA problems. This violated the original plan to fence funding for science-instrument development.

In late 2000, the SOFIA management announced that the cost and schedule estimates to complete the aircraft development were grossly inadequate. 10. To help solve this problem, NASA Headquarters offered matching funds for any money that could be liberated at Ames. The new SOFIA Program Manager targeted the ~$2M unspent AIRES funding.

11. In the spring of 2001, Ames management reassigned the AIRES management team and some engineering support to other Ames projects. USRA informed the team that AIRES should prepare a plan to reduce its estimated cost, and would organize an external committee to review the plan. The team reorganized, with the instrument scientist as manager, and in five weeks before the review formulated a descoped version of the instrument called AIRES-X, which would cost less, retain unique scientific

HISTORY (4)

capability, utilize the considerable assets so far developed, and permit eventual upgrade to the full instrument. A young manager from the Ames staff joined the team in time to help prepare for the review. 12. Under full-cost accounting, the annual cost per civil servant had risen from $14k in 1997 to over $300k in 2001. Current rates were used to develop an AIRES-X cost estimate, but could not be considered reliable because future rates were uncertain.

The review took place at Ames in July 2001. The reviewers and AIRES team had been given a charter to prepare for the review. 13. However, at the beginning of the meeting, the USRA Chief Scientist instructed the reviewers to cancel AIRES if answers to any of the following questions (which he presented for the first time that morning) were negative: **(1) "Is it [AIRES-X, the descoped version of AIRES] a scientifically viable instrument? (2) "Has the Team demonstrated it has the technical know-how to get the job done within budget?" (3) "Has the Team demonstrated it has the management in place to assure that no further over-runs occur?"**

The reviewers' written summary showed they had misunderstood sensitivity and resolution analyses presented; their comments were rebutted in the written response by the AIRES team. With these corrections, the committee's qualified "yes" to question (1) would presumably have become unqualified. Regarding question (2), the reviewers found the AIRES team to be technically competent, but that AIRES-X definition was insufficient to assure completion on-time within budget. **Lack of adequate professional management (question 3) was the reviewers' most fundamental concern.**

HISTORY (5)

The reviewers recommended cancellation, based on negative conclusions for questions 2 and 3. The reviewers reported to the SOFIA Science Council, which upheld the recommendation to cancel. 14. However, the reviewers stated **"A far-infrared spectrometer covering at least the spectral range 30-100 µm at high-resolution is a *sine qua non* for SOFIA."** and recommended that a competition for providing a facility spectrometer be launched promptly by USRA. They commented that the AIRES team would have an advantage over other proposers because of its significant technical accomplishments. 15.

In early 2002, 14 knowledgeable scientists (below) submitted a white paper for NASA's Space Science Roadmap Revision to encourage the prompt development of a SOFIA Facility Spectrometer (SFS) with the characteristics of AIRES. They concluded: 16. **Much of SOFIA's justification was based on science enabled by high-resolution, far-infrared, imaging spectroscopy. If developing the SFS is long delayed, so also will be much of the promise of this unique observatory. We urge endorsement of a far-infrared facility spectrometer development for SOFIA, to begin as soon as possible.**

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HISTORY (6)

17. In the spring of 2003, a consortium of the ASIAA (Academia Sinica Institute of Astronomy and Astrophysics, Taiwan), the Steward Observatory of the University of Arizona, and Ames presented to USRA a plan to complete development of AIRES. The plan included considerable support from the non-Ames partners, which would have reduced SOFIA's cost substantially. The plan was rejected without a formal response from USRA and the Science Council. A subsequent inquiry was rejected by the new chief of the Ames Science Directorate. 18. At the time there was much concern about the health of SOFIA in general. There seemed to be a perceived appreciation for the sacrifice of AIRES to help solve the observatory's problems.

Work at Ames continued at a low level until 2005, to complete nearly 100% of the mechanical design of the spectrometer, including ~80% of the fabrication drawings. A description of AIRES' justification and status, and some lessons for future instrument proposals, was published in 2008[2].

References:

1. Michael R. Haas, Edwin F. Erickson, Sean W. J. Colgan, James A. Baltz, and Dana H. Lynch, *Design Considerations for a Large Airborne Infrared Echelle Spectrometer (AIRES)*, in 1995 ASP Conference Series **73,** 531 "Airborne Astronomy Symposium on the Galactic Ecosystem: From Gas to Stars to Dust", Michael R. Haas, Jacqueline A. Davidson, and Edwin F. Erickson, editors.

2. Edwin F. Erickson, Michael R. Haas, Sean J. W. Colgan, Jessie L. Dotson, Janet P. Simpson, and Erick T. Young, *AIRES, an Airborne Infrared Echelle Spectrometer for SOFIA*, 2008 Proc. SPIE 6678, paper 13.