Common Threads In Project Management: Presentations, Notes, and Lessons

Gemini Lessons Learned Workshop

Parksville, BC
July 8-9, 1999

Compiled by National Research Council Canada

CONTENTS

Presentations and Notes

Round Table Discussions and Common Threads

Round Table Discussion

Common Threads

General Principles for Gemini Partner Interactions

1. The primary goal of the Gemini project is to provide superior facilities to produce world-class science.

2. The Gemini partnership was formed to realize this goal.

3. The partnership seeks to take advantage of the complementary strengths of the individual partners to achieve a whole which is greater than the sum of its parts.

4. It is recognized that the partnership has designated the IGPO as the steward of its limited resources. The IGPO has the responsibility of synthesizing the scientific aspirations of the partners into a single, cost-effective program.

5. It is also recommended that the individual partners are the stakeholders in the enterprise and are making major intellectual, technical, and financial contributions to the program. They are not commercial vendors.

6. It is accepted that there will be healthy tension between the capabilities and the costs of program elements supplied by the partners. We are committed to resolving these issues in a collegial and professional manner.

7. The partners, including the IGPO, will actively work to foster mutual respect among all people throughout the partnership.

8. Open two-way communications among the partner and IGPO team members are essential to the success of the Gemini effort.

9. The goal of all those involved in negotiations will be to obtain and execute agreements that are fair and balanced with respect to the interest of both the partnership and the individual partners.

10. Given the scale of the components of the instrument program, the use of good project management techniques is essential to meeting Gemini program goals.

11. Formal agreements must be as simple as possible, consistent with clearly defining the terms and specification of the mutual expectations of the involved parties.

Note: These principles are provided as developed and accepted in July 1997 by the Gemini partners.

Agenda

Wednesday, July 7

7:30 pm - 9:30 pm - Opening Reception (host: Canadian Gemini Office)

Thursday, July 8

7:30 - BREAKFAST
8:30 - Welcome and Opening Remarks (Andy Woodsworth, Matt Mountain)
8:40 - Goals and Organization of the Workshop (Andy)
8:50 - Gemini Instrumentation Overview (Doug Simons and Jim Oschmann)
9:45 - UK Gemini experiences (Adrian Russell, Simon Craig)

10:30 - Coffee

10:45 - GNIRS experience (Sidney Wolff)
11:30 - AAO experience with the 2dF and the VLT (Keith Taylor)

12:00 - LUNCH

1:00 - The Keck Experience (Fred Chaffee - remotely)
2:00 - GMOS (Rick Murowinski)
2:30 - Instrument Software (Doug Simons)

3:00 - Break

3:15 - International collaborations (Andy and Adrian)
3:45 - CCD Detectors (Richard Wolff)

6:00 pm - DINNER
7:30 pm - 9:30 pm - Reception (host: Gemini Observatory)

Friday, July 9

7:30 - BREAKFAST
8:30 - University of Florida (Charlie Telesco)
9:00 - IR Imagers for Gemini and Subaru (Klaus Hodapp)
9:30 - Altair adaptive optics system (Andy and Glen Herriot)

10:00 - Break

10:30 - Designing to cost (Jim)
11:00 - Common Lessons Learned from various projects (All)

12:00 - LUNCH

1:00 - Lessons Learned (continued); summary and discussion of findings

2:45 - Closing Remarks (Andy and Matt)
3:00 pm - Adjourn

Attendee List

Australia (3)

Keith Taylor	Anglo-Australian Observatory
Jan van Harmelem	Australian National University
Peter McGregor	Australian National University

Canada (8)

David Crampton	National Research Council
Severin Gaudet	National Research Council
Glen Herriot	National Research Council
James Hesser	National Research Council
Simon Morris	National Research Council
Rick Murowinski	National Research Council
Andy Woodsworth	National Research Council
Tyson Hare	National Research Council

UK (5)

Margaret Aderin	University College London
David Robertson	University of Durham
Pat Roche	Oxford University
Terry Purkins	UK Astronomy Technology Center, ROE
Malcolm Stewart	UK Astronomy Technology Center, ROE

US (15)

Andy Flach	Gemini Observatories
Fred Gillette	Gemini Observatories
Matt Mountain	Gemini Observatories
Jim Oschmann	Gemini Observatories
Doug Simons	Gemini Observatories
Fred Chaffee - remotely	W.M. Keck Observatory
Hilton Lewis	W.M. Keck Observatory
David Cowley	Lick Observatory
Mark Trueblood	NOAO
Sidney Wolff	NOAO
Richard Wolff	NOAO
Thomas Kisko	University of Florida
Charles Telesco	University of Florida
Klaus Hodapp	University of Hawaii
Hubert Yamada	University of Hawaii

Introduction

Recently, I was privileged to be at the summit of Mauna Kea for the Gemini dedication. The ceremony was handled very smoothly, and at the closing the ventilation gates were opened, allowing the sunlight to stream in and light up the new telescope. I really did feel moved, and very proud. After eight years of effort from an international collaboration, we now have a beautiful telescope that can take diffraction-limited images in the infrared. But we don't have any instruments, except for what we borrowed from the University of Hawaii, and we are not going to have more than one for quite a while. The Keck telescopes have experienced similar lost scientific opportunities because of delayed instruments.

Why are the instruments so often delivered very late and well over budget on large telescopes? What lessons can we learn from our experiences that could help us to avoid repeating the costly mistakes of the past?

To explore this, the Gemini partnership collaborated with the Keck Observatories to organize a workshop in Parksville, British Columbia. The workshop, which was hosted by the National Research Council of Canada, lasted two days. The participants were very frank and open in discussing their experiences with building instruments for large telescopes. It quickly became apparent that there are many common themes connecting the experiences of the various instrument teams, and of the instrumentation programs of both Keck and Gemini.

These themes, broadly, were:

- The importance of good project management
- The need to learn and use "design to cost" techniques
- The importance of trust, respect and good communications in partnerships
- The need to provide sufficient incentives for groups to want to build instruments for Gemini, given the potential for severe financial problems
- The need for rapid conclusion of contract negotiations
- Difficulties with the EPICS software causing schedule overruns

The attached documents provide edited versions of most of the presentations, as well as of the discussion during and after the presentations.

Andy Woodsworth
Canadian Gemini Project Manager

Editor's Note

These proceedings contain presentation notes and outlines, discussion notes, and presentation slides from the Gemini Lessons Learned Workshop. The structure of the proceedings is intended to follow in a similar manner the structure and nature of the workshop itself. Presentation and discussion notes can be considered 'minutes' taken by me during several of the workshop presentations. Presentation outlines are a transcription of presentation slides. Presentation slides (which have been edited for sensitive content and modified in format for uniformity) are provided whenever they were made available. These are followed by notes generated from the round-table discussions of some of the more frequently raised issues, and finally a list of the common threads are extracted out of these talks.

From the presentations it became evident that several issues were prominent in the discussion, and as such, these topics were selected for the round table discussion period. The workshop participants examined the definition of the 'customer', the definition of and use of 'contingency', the issue of a standard allowance for overhead, providing incentives for finishing projects on-time and on-budget, the importance of 'real' project management and what it is, streamlining contract procedures with the intent of improving schedule and budget deliverables, software issues and the effect of EPICS on instrumentation projects, and international collaboration issues.

From further investigation of the presentation and discussion notes and slides, many common thread issues were discovered. Several project management, instrumentation, and contract issues are outlined. The current lack of understanding of the definition and implementation of proper project management was the most relevant project management issue across all projects. Contract negotiations are seen as a dreaded management task, mainly due to the perceived time requirements on time strapped resources, and set projects off on the wrong foot. Software inconsistencies and serious EPICS considerations pose problems across all instrumentation projects. These are the major issues that should be considered and addressed in future instrumentation projects.

These proceedings are presented to the workshop attendees and general Gemini community in hopes that some important information can be drawn from the experience of others, for the improved well-being of all Gemini partners.

Tyson Hare
Canadian Gemini Project Office

The UKIRT CGS4 Experience — Matt Mountain – IGPO

Presentation Notes

- CGS 4 design goals were over constrained and over zealous. As a result, the instrument came in too big, too heavy, and over budget.
- The use of new technology (AutoCAD, CNC Machining, Flexure and Temperature FEA) had a steep learning curve and required a significant amount of training which led to increased costs.
- Using IR arrays for spectroscopy turned out to be complicated and led to complex software requirements.
- It was decided that proper project management was needed halfway through the project. Only when complexity demanded PM was it fully integrated as a necessary and effective tool.

Gemini Instrumentation Projects

- Build/Design to budget – capped budget set at conception based on instrument requirements. A contractual agreement with certain restrictions and requirements was drafted and approved. As a result of under-estimating and under-budgeting, only one instrument will be ready for both Gemini North and South by operational handover.

Lessons Learned

- There is a need to balance: science and performance capabilities, innovation and creation, and cost and risk
- Delivery of a highly competitive scientific capability is a requirement.
- Adopt effective project management from the beginning.
- Use better estimates for better results estimating.
    - 8 m instruments actually cost ˜ $3M - $8M, not $1M - $1.5M, when all costs are included

Discussion Notes

- Detailed engineering needs to be considered with science requirements from the beginning planning stages.
- ‘Closed loop’ design and scheduling is required.
- Small changes in workscope or schedule can have a significant overall effect on the project deliverables.
- Run schedules out to completion and watch the effects of changes as they are made. This approach is common practice in the aerospace industry.

Presentation Outline

NIRI Lessons Learned

- Manpower competition with other instrument projects within IfA was detrimental early on.
- A single person was juggling the roles of Project Scientist/Engineer/Manager as well as broad duties at IfA.
- Impressive level of efficiency/output through use of shared IDEAS.
    - handful of engineers handling all drafting duties

GNIRS Lessons Learned

- Lack of Project Management and cost control.
- Significant tension existed between GNIRS team and IGPO, which affected communication.
- GNIRS team was unresponsive to design criticism from review committees.
- ‘Not Invented Here’ syndrome.
- Resource conflict with NOAO and other Gemini projects.

GMOS Lessons Learned

- Distributed roles of Project Scientist/Engineer/Management teams confuses ‘chain-of-command’.
- Build-to-cost approach not implemented early in the project.
- Severe competition with other Gemini instruments exists.

HROS Lessons Learned

- ~ 6 Project Managers over lifetime of the instrument resulted in continuity problems – impossible to maintain a teamwork environment.
- Strong optical design team but the mechanical engineering team had problems.

T-ReCS Lessons Learned

- Initial estimates for time needed for drawings may be too low, though this may be compensated for (through contingency) later in the project.
- Overall this is a good team but only ‘1 deep’ in nearly all areas which leads to a higher amount of risk.
- This issue leads to concern for possible impacts on schedule.

NIRI Controller Lessons Learned

- Suffered from disruption in key Electrical Engineering position.

- Time needed for EPICS integration badly underestimated.

NIRI Arrays Lessons Learned

- The most successful element in the entire instrument program.
- Close working relationship between SBRC and NOAO/Gemini was invaluable. This relationship led to a myriad of detailed program choices that benefited both parties.

CCD Controller Lessons Learned

- This project relies too heavily on ‘external’ components beyond the control of the group responsible for integration (SDSU, EEV, GMOS).
- Software resources at NOAO are inadequate to maintain schedule.

CCD Lessons Learned

- CCDs are not ‘off-the-shelf’.
- CCDs are not all the same – when you buy one you buy the promise that the next one will be ‘perfect’.
- There exists a mutual relationship between CCD manufacturers and customers – with each CCD iteration performance increases and price decreases.

Altair Lessons Learned

- Unclear science requirements precipitated long delays.
- Extreme tension existed between IGPO and NRC early on.
- Resource conflict within NRC resulted in delays for two Gemini instruments.
- This is a demonstration of a project that has good and bad aspects.

Calibration Unit Lessons Learned

- The initial design was too complex – eventual redesign resulted in a reduction of both the cost and complexity and satisfied the project science requirements.

Gemini Lessons

- Instrument manpower resources within IGPO are too thin to keep up with ‘demand’ from teams around the globe.
- Workscopes and contracts negotiations take too long to execute after a decision is made to build an instrument.
- Formally reviewed budgets (cost to complete) should be prepared at all major milestone reviews.
- Most partners do not have deep labour resources.
- Long term, full time, permanent positions are important in keeping ‘good’ engineers.
- Even Gemini IGPO is ‘1 deep’ in many areas, but is a competing and ongoing operation.

- Budgeting and scheduling problems, along with other Project Management issues will result in one Gemini instrument being delivered ‘on-time’.
- Adding up all cost overruns and schedule slips will result in a significant project overrun and schedule delay.

UKGPO Experiences — Pat Roche – UK ATC

Presentation Notes

A & G Lessons Learned

- Lost expertise due to RGO ‘restructuring’ was costly.
- RGO environment had significant effect on many UKGPO managed projects – including A & G, WFS, and Coating Plant.
- Suggestions for checking the competency of (estimates from) subcontractors:
  - get references – check past work
  - do some research, both background and financial
  - look at the experience of the employees

GMOS Lessons Learned

- The work for GMOS was divided approximately 50-50 in mechanically and optically separable units.
- Too many management team members are involved – there is no one ‘project manager’ to report to.
- Mechanisms to deal with international collaborations must be further examined to insure international partnerships can be successful.

HROS Lessons Learned

- 6 years to CoDR, 3 more years from CoDR to delivery – why? This was the primary instrument that the UK wanted.
- OSL linked with MSSSL to provide backup for University group.
- There were still delays from CoDR to PDR due in part to difficulties in recruiting and retaining staff.
- HROS now approaching PDR – general instrument definition period must be shortened.

MICHELLE Lessons Learned

- Conceived as a take-off of CGS-4 and SCUBA.
- Ended up as a complicated instrument because of feature creep due to the late instrument start date.
- Too much time was spent on the design prior to the CoDR.

Discussion Notes

- UK Gemini contracts have had a very significant impact on the rest of the UK ATC astronomy program.
- Only organizations with deep pockets can afford to sign a Gemini contract as currently constituted.

- Direct cost-only formula reduces the apparent cost to Gemini but increases the cost of any overrun to the instrument provider. This format disguises the true scale of the endeavor.
- Overhead costs are different for different NGPO's
- The project schedule should be considered a critical scientific consideration.
- A mix of simple, inexpensive, and low-risk instruments and more complex, capable, and higher-risk instruments reduce the potential liability for delays. But simple instruments must be kept simple.
- Reuse existing designs.
- How are groups going to be persuaded to undertake similar projects in the future?
- Ground-based instrument projects are viewed as being less successful in meeting budget and schedule deliverables.
- Perhaps more workshops are needed – instrument builders, management committees, and engineers.
- Use of contingencies should be further examined.
- How can the use of contingencies be useful in project planning and scheduling?

Gemini Lessons Learned
The UKGPO Perspective

Adrian Russell and Patrick Roche
UK ATC

A&G

- **Initial project work to CoDR was done without being told what the budget was**
  - IGPO no longer do this
- **Was delivered for August 98 to keep 1st light schedule, but not used until November 98**
  - with hindsight this time could have been used for better testing at Zeiss
- **IGPO staff did the commissioning**
  - time pressures meant lack of training. Zeiss/UK commissioning support planned from the start would have helped a lot. Instead people were pulled out at short notice
    - In the case of a telescope sub-system I understand why this was not possible (there would have been dozens of people from all the sub-system groups getting in each other's way)
- **The Zeiss sub-contract went well**
  - all the work up front in specifying in detail the requirements paid dividends

WFS

- **UK-CA split of work was decided initially to try and keep everyone happy**
  - this took a lot of negotiation, but with hindsight it would have been better to split the work into sub-packages that were fully specifiable and testable at each partner site
- **When Charles and Nick left RGO we did not stop the project and regroup**
  - instead, in good faith, we poured ever more effort onto the project in an attempt to keep on track for 1st light
  - we should have stopped and taken joint stock and
    - either: hired more effort and assigned a new project scientist at the ATC
    - or: IGPO take over work sooner

Coating Plant

- **Closure of RGO**
- **Lack of internal financial control and review**
  - we should have spotted the problems sooner
  - made worse by closure of RGO
- **Choice of contractor**
  - a simple financial check of a company can be made quickly and cheaply. This may have prevented us placing the work with Gencoa.
- **No Project Scientist or equivalent**
  - some kind of physicist involvement could perhaps have identified issues with Gencoa sooner

GMOS

- **The specification for the instrument was a compromise to keep both the UK and Canadian PIs happy**
  - After a huge amount of negotiation the inclusive set of specifications was adopted
  - with hindsight this lead to the project going over the budget. Even with the WS increase the UK and CA will still lose money
- **There should have been a single project manager**
  - APGR/AW fought to have two. I now think I was wrong.
  - What we have is a solution that has allowed the two countries to collaborate well, but it did not keep to cost/time
  - A single manager would have helped keep on cost/time - but would it have worked as a collaboration? (Discuss)

GMOS 2

- **We really tried to run it as a single project**
  - The split of work resulted in the UK providing crucial finance & planning information to CA (on CA spend)
  - with hindsight it would have been better to agree to maintain two sets of books/plans for each half of the work and to link them at the very top level only
- **The ROE-UoD work split was somewhat arbitrary**
  - split was designed to share the value of the work. Was this the best way?
- **There was no project scientist on Blackford Hill**
  - I now believe passionately that each collaborating group must have it's own scientific leadership
  - although this increases the risk of specification creep (as a high power of the number of scientists!), without a local project scientist, the engineering team is not as focussed

HROS

- **The initial instrument concept was the inclusive set of the aspirations of the community**
  - the OSL group wanted to rise to the challenge of doing it - before there was a PS to mediate
- **Success - the specification was simplified massively after CoDR**
  - challenge - to get this to happen as part of the project rather than by "failing" a review
  - Used Rick McGonegal to beat up OSL into accepting a new approach
- **OSL linked with MSSSL to provide back-up for University group**
  - but still delays from CoDR to PDR, difficulties in recruiting and retaining staff

GCal

- **Prediction rather than lesson...**
  - We are not responsible for the GCal software
    - it was removed to save money
    - we are very worried about this and would NOT recommend this for the future - despite worries about the EPICS learning curve

- **All of the lessons from previous ROE instruments that have been great successes (IRCAM, CGS4, UKT14, SCUBA) suggest that…**
  - the instrument must be tested fully in the lab with the real software it will use

- this has been a Donald Pettie tablet of stone over the years and we ignore it at our joint peril!

Summary of Lessons learned...

At the ATC we held an internal lessons learned meeting (with Pat and Jim Hough). What follows is that the UK ATC has adopted as a set of lessons learned...

Summary of Lessons (1)

- **Systems should not be released until fully tested**
  - i.e. we believe we should not let an instrument out of our labs until it is fully tested (with the real software and a telescope simulator/flexure rig)
- **Commissioning of ATC equipment must be included in Workscopes**
  - this is an ATC perspective as a result of the Gemini experience
  - If not you will end up sending out a team to sort out the problems without the benefit of planning the effort to do so (and possibly at your own expense)
  - Need active Gemini Observatory staff involvement at Instrument test and acceptance
- **Unscheduled commissioning must be evaluated dispassionately**
  - the Customer must know (and see) the knock on consequences (see above)

Summary of Lessons (2)

- **Inherited projects are new projects**
  - and must be re-evaluated as such (WFS)
- **Requirements must be fixed**
  - avoid specification creep
- **Reviews must be more frank**
  - sweetening the pill does not help. Be honest - sort it out now or it will only get worse
- **Internal Review must be conducted**
  - a project should not reply on external oversight to be sure it is OK. There is too much of a "pass the review - therefore OK" culture developing
  - these reviews should be at sub-system and module level as well as top level overall reviews

Summary of Lessons (3)

- **Local Project Scientist should be appointed to each project**
  - the ATC will no longer become involved in a project without a local Project Scientist (a Matt Mountain or a Phil Puxley type PS as opposed to any astronomer)
- **Single point authority**
  - there should be a single person in ultimate control of a project (as opposed to equal status managers)
- **Saying No**
  - to avoid specification creep
  - to additional work that prevents you from delivering on your project!
- **Openness**
  - sort it out now or it will only get worse

Summary of Lessons (4)

- **Systems engineering**
  - we now believe that this must be adopted formally
  - in the past this has been done by a combination of the Project Manager and the Project Scientist for ROE projects
- **Deliverables between collaborators must be explicitly defined**
  - sub-systems must be fully testable before delivery (and should have been tested)
- **Financial Review**
  - not a Gemini only lesson, but the ATC now requires all it's Project Managers to report to the Management Board monthly on progress, schedule and cost

Additional Thoughts

- **UK Gemini contracts has had a very large effect on the rest of the UK astronomy programme.**
- **Only organizations with deep pockets can afford to sign up to a Gemini contract as currently constituted.**
  - In the UK, the only source of funding is through PPARC, but this may not be true everywhere.
  - Imbalance : no profit - can only lose money or break even
- **Direct cost only formula reduces the apparent cost to Gemini but increases the cost of any over-run to the instrument provider. Disguises true scale of the endeavour**

More Additional Thoughts

- **HROS now approaching PDR: delivery scheduled in ~2 years. BUT project has been rumbling on for about 6 years now. Must shorten the instrument definition period.**
- **Schedule is a critical scientific consideration.**
- **A mix of simple, inexpensive, low-risk instruments and more complex, more capable instruments reduces the potential liability from delays. But simple ones must be kept simple!**
- **How do we persuade groups to go through this (again)?**
- **Start-up costs are very substantial, particularly in software and management**
- **Re-use designs and solutions to minimise cost and risk - NIFS**

UK Lessons Learnt

- **Plan to hold a PPARC Lessons Learnt Meeting probably late this year**
- **Bring together Particle Physics, Space Physics and Ground-based instrument groups.**
- **Ground-based instrument projects are viewed as being less successful in meeting budget and schedule than those undertaken by the other groups.**
- **Output from this workshop will feed into this meeting.**

Presentation Outline

- Management given too little attention.
  - Director – too remote; important project buried too deep.
  - Deputy Director and Engineering Manager – Relied too heavily on reports from project team; did not make independent assessments.
  - Project Managers – Assigned to complete other projects when lead engineer left; no time for management.
  - GNIRS Project Manager/Engineer – Design and Management functions should not be combined in project of this size.
- Design reviews failed to detect problems
  - Technical questions were raised but not pursued.
  - All suggestions raised by review committee were dismissed.
  - Budget and schedule were not part of the review.
  - Gemini set terms of review.
  - Poor interface with senior NOAO management (USGPO & IGPO were in contact with lower level NOAO management).
- Absence of System Overview
  - Financial and schedule information available to everyone; cost and schedule overruns should have been obvious.
  - Comparison of size and comparison with other instruments (both internal and external) were not made.
  - No flow down of requirements and no dynamic trades against error budget
- Project staff was inexperienced.
  - Project Engineer and Scientist were not familiar with NOAO management practices.
  - Project management was not enforced.
- Project could not have been delivered on time or budget
  - Costs were unrealistic and negotiated too early.
  - There were many ICD changes (volume/weight).
  - EPICS environment was yet to be defined.
  - Over-ambitious goals were set.
  - “Include as many upgrades paths as possible”.
  - Systems implications were not taken into consideration.
- Proposal Design was scrapped immediately.
  - Original design possessed limited scientific capabilities.
  - Space envelope was changed
  - Weight budget was reduced to allow for electronics.
  - OWIFS was added.
  - Inexperienced project team understood new design in detail only.

GNIRS Lessons Learned

- Management Matters
  - Provide sufficient time and manpower for project management.
  - Use managers whose strengths and weaknesses are known.
  - Use project management tools. Reviews can be a constructive design tool when:
    - viewed as a design tool
    - constructive criticism is generated and recognized
  - Monitor effectiveness of use at quarterly intervals.

- Common sense and systems engineering matter.
  - Look at the forest and the trees
  - Flow down requirements so money is spent in correct places.

- Estimate costs and fund in stages; agree to fixed price only at CDR.
  - Invest enough resources prior to CoDR to obtain good ongoing estimates, flag problems, rescope early.
  - Recost project taking systems issues into account at every major review stage and prior to signing workscope amendments.

- Building to cost is everyone's responsibility
  - Couple science goals to cost.
  - Avoid mission creep.
  - Be prepared to descope. Have a mechanism for iterating with science requirements.

- Develop metrics to estimate costs.
  - Don't bankrupt your supplier.
  - Gemini instrument builders cannot limit risk through overhead, profit, contingency, and excessive charges for change orders.

- Minimize interfaces
  - Common subsystems may be a false economy.
  - Define in a timely way.
  - IGPO must act as prime contractor.

- Use widely adopted (commercial) standards.
  - Easier to find staff.
  - Work would not be a professional dead end.

- Make the review processes effective.
  - Schedule at the right time relative to the project achievements.
  - Include cost and schedule in review.
  - Report to top level management.

The Keck Experience — Fred Chaffee and Hilton Lewis – Keck

Discussion Notes

- Don’t reinvent the wheel.
- Why is so much effort being put into developing nearly similar, expensive instruments?
- It may be more advantageous to share on a wider range of similar instruments.
- Successful instruments are partly related to the quality and experience of the engineering team.
- Having instrumentation teams saturated/overloaded with work is bad for two reasons:
    - ‘1 deep’ problem
    - Not enough resources are available for the number of instruments to be built.

Lessons Learned at Keck

Frederic H. Chaffee, Hilton Lewis, Mark Sirota, and Peter Wizinowich
W.M. Keck Observatory

LESSONS LEARNED

- **Early Phases**
  - Effects of science drivers on cost & schedule imperfectly understood
    - Results in overly optimistic effort & cost estimates
  - Evaluation of phase A proposals need to include more than science goals. Should include:
    - Team track record & experience
    - Management plan & team size
    - Compatibility with existing observatory infrastructure
    - Maintainability after delivery
  - Better oversight of projects in early phases is essential, via organized reviews

LESSONS LEARNED

- **Middle Game**
  - Need strong & consistent project management
  - Avoid mission-creep
  - Standard reviews (PDR, CDR, Acceptance) are essential
  - Review boards have teeth & report back to the funding body & the customer (the observatory)
  - Maintain close contact between the instrument group & the observatory through frequent telecons & on-site visits

LESSONS LEARNED

- **End Game**
  - Must be careful not to underestimate resources needed for commissioning
  - Software is much harder to change after commissioning because of factors like:
    - Inadequate documentation
    - Imperfect understanding of software by observatory staff
    - Inadequate test suites & simulation capability
    - Limited time available for full-up system tests

LESSONS LEARNED

- **Need plans for long-term support from instrument group**
  - Alternatively, need much stronger standards for documentation & infrastructure
- **Use of non-standard infrastructure (hardware & software) makes maintenance much harder and costlier.**

LESSONS LEARNED

- **Parting Thoughts**
  - Observing time lost due to late commissioning is a real cost, far greater than the cost of the "marching army" needed to complete the instrument
    - Lost competitiveness
    - In extreme cases, the instrument itself becomes obsolete.

The AAO Experience – 2dF and VLT Keith Taylor – AAO

Presentation Notes

Learning Lessons

- 2dF
    - A project management free zone.

- OzPoz
    - Assuming ESO project management styles.

Discussion Notes

- Engineers find project management / accountability task alienating, even for tasks as trivial as reporting percent-of-task-complete figures.
- Resources should not be held to estimates, rather estimates should be used as a management tool.
- The management process should be a positive and educational experience.
- Determine what should be rewarded, fancy gadgets and creativity or finishing set objectives on-time and on-budget.

The AAO Experince

Keith Taylor
AAO

Gemini's Lessons Learned Workshop
Questions to be asked …

- **Are instruments more difficult to cost than telescopes?**
- **Do instruments have intrinsically higher risk factors?**
- **How do we calculate the real cost / benefit of building an instrument?**
- **Who pays the cost / receives the benefit?**
- **Is it necessary to take risks to get an interesting product?**
- **How do you quantify the risks? and who pays for them ?**
- **Why do sane organizations take on insane contracts?**
- **Have NGPO safety nets been detrimental?**
- **How do we achieve fair competition in a climate of variable risk assessment?**

Gemini's Lessons Learned Workshop
Some less obvious questions

- **Should suppliers be ISO-9001 compliant ?**
- **WHO IS THE CUSTOMER ?**

Learning Lessons AAO-style
2dF (1990-97) …

- Seat-of-the-Pants project management style
- However … Coherent / Focussed / Motivated Team
- Outcome … ~Success (at ~$5M costs)
- (~2 yr. delay but <u>**NO**</u> hardware cost growth)

- **OzPoz (1998 -) …**
  - Sensible contracts (+TS; SoW)
  - Rigorous PM protocols
  - Rigorous cost controls
  - Good communications
  - Outcome … Success, so far (passed PDR in Apr'99)
  - (growing cost and time pressures !)

2dF, case study

- **Highly complex robotic fiber-fed spectrograph**
  - mounted at AAT Prime-focus
  - massive 4-element corrector/ADC
  - massively multiplexed and double-buffered robot
  - very complex software control
  - pipe-line reductions from first-light
- **High risk project with several potential show-stoppers**
  - Corrector / Robot / Astrometry / Bare-fibers
- **No feature creep or de-scoping (constant re-scheduling)**

- **In-house project (except for corrector)**

OzPoz, case study

- **Rigorous T.Spec. & S.of W. protocols;**
- **Rigorous (but reasonable) contract negotiations;**
- **ISO-9001 compatible procedures;**
  - Monthly reporting
  - 4-monthly progress meetings (+ PDR ; FDR)
  - Full documentation requirements
  - Interface control arrangements
  - Configuration control
  - Change control boards
- **Protection for customer & supplier.**

Some abiding myths

- **A well managed project is a good project;**
- **A badly managed project is a bad project;**
  - Billy Wilder quote: "I never heard anyone say that they really must go to a particular movie because it came in on time & in budget"
- **Cost over-runs are largely due to "feature creep";**
- **The customer is always right;**
- **A financial "safety net" is good protection;**
- **We're always too optimistic in our estimates;**

Some home truths

- **The most creative individuals are usually most unmanageable;**
- **Instrumentation is "high risk" if its worth doing;**
- **Instrumentation is often done by small organizations who can't shoulder risks;**
- **Shonky project management is endemic;**
- **The risks should be shared, pro-rata (?)**
- **Good communications are almost everything.**

Feed-back from AAO staff

- **PM protocols are good for Managers but bad for the Workers;**
- **However … the workers think PM protocols are necessary;**
- **The AAO hasn't yet got it right;**
  - level of task detail (all tasks should have deliverables)
  - necessity of up-front plans (how do we handle program changes?)
  - how do we protect workers from PM procedures?
    – how do we monitor without setting people up for failures?

Feed-back from customer (ESO)

- **Generally good**
- **AAO is seen to be strong both technologically and managerially**
- **Good lines of communication (essential)**

- **But …**
  - Building to cost as defined at proposal (CoDR) stage

Gemini from a distance

- **Fixed-price contracts (usually at unrealistic cost)**
  - Risk shouldered by NGPOs
  - Contract inflexibility
  - Supplier works with cushion of uncertain depth
- **Result**
  - Clean contract interface for IGPO
  - Gives IGPO illusion of safety
  - Gives supplier illusion of safety

Where do we go from here?

- **IGPO needs to re-assess its approach to contracts**
  - Realistic costing (with error budgets)
  - Realistic risk assessment
  - Pro-rata distribution of risk management
  - Escape clauses for both parties
  - No NGPO intermediary?
- **IGPO needs to actively monitor contracts**
  - More IGPO staff?
  - More ownership of project by IGPO
- **Contractors need to be more professional in their PM?**

Conclusions

- **Contract to a not-to-be-exceeded cost at CDR**
- **Contract escape clauses for both sides**
- **No financial safety nets**
- **Contractors should be ISO-9001 compliant?**
- **Up-front payments**
- **Greater IGPO engagement**
- **Gemini pays uniform (say 20%) overheads**
- **Result:**
  - IDF plans become fuzzier
  - Groups will [more happily] engage with Gemini in the future

The GMOS Experience **Rick Murowinski – NRC**

Discussion Notes

- The important question should not be ‘how much time will it take a person to do this task’ but ‘how much time will it take to train a person then have them do this task’.
- Some questions for consideration:
- What are the effects of NGPO agendas?
- How do international collaborations effect instrumentation deliverables?
    - they are costly but intellectual exchange may be worth it
- Resource splitting shouldn’t happen (ex. GMOS/Altair).
- Resources devoted exclusively to one project instrument seem to be more productive and effective.

GMOS

Rick Murowinski
National Research Council

GMOS

- **UK and Canadian collaboration, about 50-50 share**
  - UK contributions by ATC and University of Durham
- **Two project managers and project scientists**
  - One system engineer, one lead manager
  - single project interface to IGPO
  - lack of on-site scientist at ATC has made progress more difficult

GMOS Distribution of Work

- **Canadian Contribution**
  - optical barrels
  - integrated optomechanical assembly from ISS to focal plane
- **UK Contribution**
  - integrated optomechanical assembly from focal plane to detector
  - IFU
  - enclosure
  - system software

GMOS Distribution of Work

- **Importance of close working relationship between optical/mechanical/electrical/software!**
- **Is one or two scientists better? One or two managers?**
- **Project should be split into large independently verifiable and deliverable pieces, not into disciplines.**
- **Rolling grant with Durham University may have caused less accountability?**

GMOS Contract

- **Two contracting phases: initial to CoDR and a second workscope to delivery.**
  - Difficult contract negotiations for main contract
  - Workscope finally signed at end of July, 96 after 18 months of wrangling.

GMOS Workscope Amendment

- **Due to uncertainty of estimate, explicit clause to re-evaluate cost at CDR.**
- **GMOS proposed three options, more negotiations followed and an amendment agreed in Oct '97.**
  - Functionality reduced and funds increased 14%

GMOS - Cost of Optics

- **Requirement is 0.4 - 1.0 micron, with GSC-set goals for extension to 0.36 and 1.8 microns. 80% throughput.**
- **Current design is technically challenging (and expensive)**
  - use of large CaF2 to meet the IR extension
  - near diffraction limited performance, very large optics under changing gravity

GMOS Software

- **Has continually met with difficulty getting resources and progress accomplished**
  - Use of EPICS has caused a limited pool of available manpower, with augmentation to that pool being developed only over long time scales.
  - Late start both in Canada and UK directly attributable to effort being needed for other Gemini work. Both partners underestimated the effort needed to complete other software projects. "Telescope" software has a higher priority than "Instrument" software.
  - This situation aggravated by personality problems within GMOS.
- **Progress is now being made, but is critically late in the instrument development schedule.**

GMOS Cost and Schedule

- **Amendment is for 114% of workscope and reduced functionality**
  - Currently estimating 133% of original workscope price to complete GMOSs
- **Both original and amended workscope stated delivery to the telescope in Oct, 99.**
  - Currently estimating Dec, 00 (127% of original duration)

GMOS Cost and Schedule Overrun

- **Some amount of the GMOS schedule slip was caused by each partner becoming complacent about their schedule due to the perceived slippage of the other.**
- **Some amount of the schedule slip resulted from decisions taken by national project managers to not redistribute work.**
- **Some amount of both the cost and schedule overrun result from our inexperience in estimating and controlling projects.**

Instrumentation Software — Doug Simons – IGPO

Presentation Notes

Software Lessons Learned

- Software has proven to be difficult to design and implement by all instrument teams.
- Other non-instrument software teams have been successful, ex. TCS, ECS
- 'Common denominator' among instrument failures may be CICS.
- Instrument teams lead to view CICS as a template that rigidly defines software architecture. CICS demonstrated how not to EPICS.
- Main hurdles for a 'virgin' Gemini programmer:
    - ~ 20,000 lines of code
    - ~ 800 pages of documentation
    - too much Gemini software ICD's and documentation
    - difficulty grasping a rarely used programming language called EPICS

Lessons from Steven Beard

- CICS contains too many Capfast diagrams.
- EPICS comes with a substantial learning curve.
- Problems associated with a large number of State Notation Languages

Price to pay…

- Schedule impact – nearly all instrument teams have slipped software schedules and may now have instrument software on the critical path.
- Cost impact – Gemini partnership money is continuously used to train new instrument programmers to use Gemini software.

How do we proceed?

- Suggest defining a working group of:
    - core Gemini programmers
    - experienced 'external software engineers
- The working group should outline the steps involved with revising the Gemini instrumentation model, with emphasis on:
    - conformance to Gemini's existing EPICS based control system
    - ease of code development
    - adequate support for new instrument teams
    - examine a new role for Gemini in the development of code for (new) instruments
    - Gemini provides 'hard paths' where EPICS expertise already exists
    - instrument teams provide custom device drivers

Discussion Notes

- A revised (better and simpler) EPICS template is needed.
- Caution should be exercised about the instrument software that would be chosen for a template.
- Implementing a 'thin' EPICS layer may be better overall.

International Partnerships

Andy Woodsworth
National Research Council

- **Trust, understanding, communication and respect are essential for good partnerships**

International Partnerships

- **Canada and UK have two partnerships**
  - GMOS (true partnership)
  - Wavefront Sensors (equivalent to a subcontract)
- **These are quite different in character**
- **Canada and Chile are now developing a new partnership for the Gemini Science Archive**

GMOS Partnership

- **NRC and PPARC equal status**
- **Within the UK, Durham performs much of the UK work including all the science oversight**
- **Four scientists and two managers**
  - "Who's in charge?"
- **No overall manager (Gemini concerned about this from the beginning)**

GMOS Partnership

- **Not easy to have single manager; we cannot report to someone in another continent**
  - In any case, no overlap in normal working hours
- **Management role split between NRC and PPARC; different responsibilities**
- **Single formal reporting point to Gemini (Murowinski)**
- **Work split into large functional units**
  - pre-focal plane, post-focal plane, ADC, optics, …
- **Integration and test all in the UK**

GMOS Management Issues

- **Initially, hard to get agreement on scientific requirements.**
  - Both countries had different scientific goals for GMOS
- **Success is critically dependent on managers' mutual**
  - trust
  - understanding
  - respect
  - constant communications (telecons daily to weekly, occasional visits)

- **Same thing for scientists except communication doesn't need to be quite as frequent**

GMOS Management Issues

- **Different cultures, even though the language is [almost] the same**
- **(A MOS called Wanda)**
  - Canada more comfortable with informality
    - meetings, minutes, etc.
    - Canadians have little regard for status, rank, position
  - Easy to offend the other party unintentionally
- **Requires constant communication, and attention to details to keep the teams efforts from diverging**

GMOS Management Issues

- **How do you deal with sensitive issues?**
  - If your partner is not keeping to their schedule and this will affect final delivery and your own costs
  - If your partner does not place as high a priority on the project as you do
  - If you disagree with a technical direction taken by your partner
- **Cost sharing is complex**
  - Initially agreed division of effort
  - But we trade work back and forth
  - One group's work may need rework by the other
  - One group's delays may incur additional costs on the other
  - We agreed to shared costs of integration and test

GMOS Management Issues

- **How do you keep up mutual respect for the members of each team**
  - May be real differences in ability; this should not diminish respect for the individual
- **Communication, communication, communication**
- **Generally, GMOS has been a successful partnership but it has taken a lot of work (like a good marriage)**

WFS Partnership

- **UK (formerly RGO) is lead, Canada has a secondary role**
- **UK provides overall scientific oversight and management**
- **UK provides formal contact with Gemini**
- **Canada only manages its own effort**
- **Equivalent to a subcontract**

WFS Partnership Issues

- **Canada has never seen an overall WFS project schedule**
- **WFS manager is Simon Craig, also responsible for managing many other UK projects**

- difficult to get much of his time

WFS Partnership Issues

- **Considerable confusion around time of RGO closure**
  - Canada asked to take on some of UK software work
- **Much simpler structure than GMOS; we only have to worry about our part of the work**

Science Archive Partnership

- **Different countries, different issues….**
- **Chilean scientists good, enthusiastic and easy to work with**
- **Who is speaking for Chile? (Two universities and CONICYT each have different perspectives and goals)**
- **Who will contract for Chile (CONICYT or a university?)**
- **Perception of equal status is important, although capabilities and experience in astronomical archiving are not balanced**

Gemini's Role

- **Gemini needs to be sensitive to need for delicate balance in the relationships between partners**
  - Gemini has already done so, in agreeing to shared GMOS management
- **Gemini needs to be soft, or "neutral" rather than AURA-centric, in contractual language and negotiations**

What makes effective partnerships?

- **From a presentation on a Canadian Federal partnership in technology transfer to the mining industry**
- **focus on needs/wants**
- **agreement on approaches**
- **clear, common expectations**
- **well defined budget, schedule, deliverables**
- **appropriate sharing of costs, risks, benefits (buy-in)**
- **contracts to record obligations, expectations**
- **frequent ongoing contact, collaborations, communication**
- **effective project management**
- **professionalism (delivery)**
- **periodic surveys of partner satisfaction levels**
- **post project impact evaluation**

Presentation Notes

- What was new to NOAO?
    - chips (EEV), controller, software (EPICS), GMOS Dewar
- Chips, controller, and software were all late delivery items.
    - EPICS provides
        - communication protocol (channel access)
        - code control records (bad)
        - Capfast (bad)

Discussion Notes

- DHS should have a component that works with the instruments.
- No part of the DHS works outside the TCS
- Thin layer EPICS applications weaken the overall strength of the environment – use must be evaluated on an individual basis
- EPICS does what it was intended for, its real downfall is the steep learning curve.

T-ReCS
Thermal Region Camera Spectrometer

Charlie Telesco
University of Florida

- **Facility mid-infrared imager ("MIRI") for Gemini-South**
- **Under development in Department of Astronomy, University of Florida**

  - T-ReCS Development Team

- Core team: permanent UF staff

Charles Telesco	**Principal Investigator, Optics, Science**
Thomas Kisko	**Project Manager, Software**
Robert Piña	**Software/Electronics Systems, Science**
Jeff Julian	**Thermal/Mechanical Engineer**
Kevin Hanna	**Electronics Engineer**
David Hon	**Software Engineer**

- Key sub-contractor: optics design & characterization

Center for Research and Education in Optics and Lasers (CREOL)
and Florida Space Institute, University of Central Florida

Note: **The T-ReCS team has broad diverse background in instrument development, but T-ReCS is the first *facility-class* instrument. *We're willing to listen and learn.***

NOTEWORTHY EXPERIENCES

Positive:

- **We are on-time and under budget (so far)**
- **USGP Work Package Manager--efficient, active monitoring *and* mentoring (e.g., rapid appraisal of need for additional draftspeople)**
- **Generally excellent guidance and assistance from USGP and IGPO (e.g., equipment loans)**

Full appreciation gained by PI of value of, and need for, Project Manager

Negative:

- **Software**
  -- CICS did not live up to expectations
  -- EPICS, CAPFAST and SNL are less than satisfactory (EPICS vs GEM EPICS)
  -- ICD's not perfect

Contacts among teams should have been more systematic from project beginning
-- Need instrument-development "committee" (PI's and PM's) to reduce re-invention of the wheel

WHAT WE HAVE DONE RIGHT

- **We have an excellent team**
  --strong effort to make team stable, accommodate personal styles
- **All deliverables have been on-time**
- **We have a detailed BOM**
- **We have a detailed expenditure plan (BOM + staffing + everything else)**
- **We have a schedule contingency (two schedules)**
- **We have a cost contingency (the plan is less than funding)**
- **We have utilized students to supplement staffing (more than proposed)**
- **We have developed management tools, e.g. BOM, the plan**

LESSONS LEARNED / TO DO

- **Need to initiate more interaction with other instrument teams**
- **PM initially budgeted at < 0.25 FTE; have / will increase**
- **Need a simple EPICS template; working on our own**
- **Our software design needs work; but we have working code**
- **Software schedule can't be developed in advance (under current conditions)**
- **Upgrades are unknown but inevitable**
  CPU? Motorola vs. Power PC? (VX Works license change?)
  gem5 (Epics 3.12.x), gem6 (Epics 3.13.x)?
  Solaris? VxWorks?
  CICS2
- **DHS? Need an OCS and a TCS simulator?**
- **Commissioning plan needs work**
- **Get staff to work uniformly vs. last minute panic**
- **Need to work on "real" project management (what ever that is)**

QUESTION: **Is there a role for “small” university groups in development of major facility-class astronomical instruments? (~reaction to ESO report)**

UNIVERSITIES--Advantages:

- **Science driven (no “mandate” or “mission statement” to build instruments)**
- **--Personal science motivation brings energy to instrument development**
- **Broadens pool of available teams**
- **--”new blood,” new perspectives, train future instrument builders**
- **Promotes broader community support & involvement**

[Suspect] easier to monitor (fewer personnel, simpler management structure)

UNIVERSITIES--Disadvantages:

- **“One engineer deep”**
- **--fewer personnel, not so easy to shift people to “fill holes,”**
- **lower salaries (harder to compete)**

- **[Often] no full-time project manager (project by project)**
- **Larger role for sub-contractors for major tasks (may drive up cost)**

Maintaining University Instrument Teams
(Investing in the University Infra-Structure)

- **Science driven Þ guaranteed telescope time a big motivator**

- **“Requiring” subsidies:**
- **--can backfire (underbidding)**
- **--often difficult for universities to consistently subsidize**
- **(UF waived part of O/H)**
- **--ESO report right: major instruments are expensive**

- **National labs carry out certain key tasks where not available at university**
- **--e.g., optical design, non-instrument-specific S/W**

Management help may be necessary

The NIRI Experience **Klaus Hodapp – University of Hawaii IfA**

Discussion Notes

- More pressure needs to be placed on the early phase of instrument development.
- The importance of speeding up contract negotiations and instrument development cannot be understated (consider fast track instrument development at ESO).
- The half-life of an instrument should be approximately 3 years. The opportunity cost for delayed delivery is about $2000/day.
- Methods of how incentives could be provided to instrument builders should be further examined. Some payment/reward schemes could include providing funding for building/shop improvements, post grad positions, etc.

NIRI

Klaus Hodapp
University of Hawaii IfA

NIRI: Lessons Learned

- IfA Instrumentation Division
- NIRI Specific Issues
- Suggestions to Gemini

IfA Instrument Development

- Instrumentation Division (CFHT 8K×12K, IRCS,NIRI)
- IRTF (SPEX)
- P.I. Developments (AO, CCD, IR-Array)

Solutions (Instrumentation Division)

- Design Study Contract
- Concurrent Design and Fabrication (IDEAS)
- Joint Prototype Development (IRCS, NIRI)
- Common Array Controller (IRCS, SPEX)
- Sharing Designs (IRCS, NIRI, CFHT)
- External Fabrication Work
- Temporary Hires and Students

What Worked for NIRI

- Preliminary Design Contract
- Conceptual Design Review
- Prototyping (a.k.a. advance fabrication)
- Sharing with Other IfA Projects
- Upgrade Decisions (OIWFS, Grisms)
- Concurrent Design and Fabrication

What Worked for NIRI

- Weekly Staff Meetings
- Daily Checking of Fabrication Progress
- Consensus Building with Competing IfA Projects

NIRI Mistakes

- **Protracted Contract Negotiations**
- **Contract Implementation**
- **Restrictive Cost Control Provisions**
- **Premature PDR**
- **Post-PDR Panic (staffing)**

NIRI Mistakes (continued)

- **Poor Cost Projections**
- **IR OIWFS Contract Amendment (Cost)**
- **Lack of Project Manager or Chief Engineer**
- **Useless Accounting System**
- **Optics: SYNOPSIS problems**
- **Project Scientist Contract Terms**
- **Software: EPICS problems**

Future Improvements at IfA

- **Reestablish Core G-funded Technical Staff**
- **Better Cost Estimates**
- **IfA Review of Budgets**
- **Proper Machine Shop Management (done)**
- **Cost Accounting on Level 2 of WBS**
- **Streamlined Purchasing System**

Future Improvements at IfA

- **More Shop Funds for Engineers**
- **Discretionary Funds for P.I.**
- **Better Contracts for Project Scientists**
- **More Space for Staff Expansion (Hilo)**
- **Better Test Facilities (Hilo)**

Project Management

- **IfA Director**
- **IfA Executive Committee**
- **Associate Director for Instrumentation (ADI)**
- **Principal Investigator**
- **Project Manager**
- **Project Assigned Staff and Project Staff**
- **IfA Accounting**

Suggestions to Gemini

- **Treat instrument development as a scientific collaboration, not as procurement.**
- **Speed up instrument definition.**
- **Speed up contract negotiations.**
- **If instruments are built jointly, foster a true collaboration between the groups involved.**

Suggestions to Gemini

- **Always have preliminary design studies.**
- **Base cost estimates on preceding instruments, then extrapolate.**
- **Budget Estimates:**
- **CoDR: ±50%, PDR: ±20%, CDR: ±10%**
- **Build in a contingency**
- **Offer incentives for not spending the contingency**

Suggestions to Gemini

- **Always plan upgrade paths, in particular for the detectors.**
- **Have an instrument ready for quick installation of an experimental system (NIRI shell ?)**
- **Have a program of fast track instruments (NIFS is a good example)**

The Altair Experience Glen Herriot and Andy Woodsworth – NRC

Presentation Notes

- NRC implemented Mechanical Designer over IDEAS for two reason:
  - larger resource pool of users
  - cheaper
- Retest, rework, etc., were contingencies deliberately worked into the schedule.
- Design reviews are a valuable source of critical and constructive design suggestions.
- NRC provides a PS and PM for each project, which has proven to be a valuable and required resource allocation step.
- There is risk involved with concurrent design and fabrication of projects:
  - poor resource allocation
  - unforeseen design problems always arise
- Optical designer has contributed significantly to the scientific success of the instrument.
- Functional requirement specifications were an important aspect of the design.
- The use of State Notation Language was avoided except for 'quick and dirty' test scripts.

Altair Lessons Learned

- A 'Siege Mentality' developed early on.
- NRC felt pressure for 'grabbing work that we had no proven expertise in'.
- Budget disagreements existed from the beginning.
- A fundamental technology disagreement existed from the beginning.
- Project team was not well enough prepared for the CoDR.
- Poor communication between Gemini and NRC led to a 'Cold War'.
- A forum process is needed for this type of collaboration
- Fundamental disagreements between NRC and Gemini should have been handled more diplomatically.

Altair Lessons Learned

Andy Woodsworth
National Research Council

Altair Lessons Learned

- **We developed a siege mentality early on:**
- **pressure for 'grabbing' work we had no proven expertise in**
- **Fundamental technology disagreement**
  - Gemini adamantly opposed to curvature sensing; not well enough understood
- **Disagreement over budget from early days**
  - Gemini thought we had agreed to build AO for a capped amount, and believed we could do so [but even the CFHT AOB cost more than cap.]
  - Not allowed to tell PS or PM that Gemini had capped budget

Altair Lessons Learned

- **Not well enough prepared for CoDR**
- **Gemini had issues with NRC staff**
- **This led to "cold war" between Gemini and NRC**
  - Gemini stopped work for six months
  - NRC declined to restart for an additional six months
  - Contract negotiations took another eight months

Altair Lessons Learned

- **That was the experience, what are the lessons?**
- **Forum process would have handled at least some of the cost issues**
- **Should have handled fundamental disagreements much more diplomatically rather than through "street fighting"**
- **Project scientist should have been on-site, and somewhat more collegial with Gemini**
- **Many of the irritants of the time were since resolved through the Gemini partnership principles ("11Commandmants")**

Altair Lessons Learned

Glen Herriot
National Research Council

Vendor vs. Partner?

- **Gemini Principles have done much to fix this dialog of the deaf:**
- **“You’ll do exactly as we say.” versus “It’s a partnership.”**

General Principles for Gemini Partner Interactions

- **This manifesto has made a substantial improvement to relationships within Gemini.**
- **“9. Open two way communications among the partner and IGPO team members are essential to the success of the Gemini effort.”**
  - ongoing effort at communication is needed
- **In the early days, too many tongue-in-cheek statements were made in a serious manner by both sides in international meetings.**
- **It was painful to resolve difficult issues while simultaneously worrying “is he serious?”**

Chicken & Egg problem

- **Without a contract to build Altair, we could not commit to hiring specialized staff.**
- **Yet, without key expertise, the customer (Gemini) was unwilling to let a contract to us.**

Interface Control Documents

- **Not available in time to guide instrument design.**
- **Rules changed underfoot.**
- **Imposed unilaterally, signed off by Gemini without us even seeing a draft copy.**
- **Revised and re-released without notifying us.**
- **“Oh, you have to fill out (internal IGPO) form XYZ.”**

Design Reviews

- **What is expected for a design review?**
- **How much effort? We contracted for, and delivered X amount of work for a CoDR, but were criticized for having too thin a team and insufficient analysis.**
- **Presenting concept alternatives is discouraged because options distract reviewing the baseline design.**
- **But good ideas may be rejected too early. A review committee may see merit that the design team overlooked in discarded concepts.**

Successively more detailed reviews and costing.

- **Each review is of a progressively more detailed design and costing**
  - Conceptual Design review (CoDR)
  - Preliminary Design Review (PDR)
  - Critical Design Review (CDR)
- **This procedure is in general, good.**
- **Designers don't go too far down the wrong road. The earlier you fix a mistake, the cheaper it is.**

But… progressive costings wear out vendors.

- **Builder can't "cut metal" until after CDR, several years in future.**
- **Thus, builder is not really a "qualified customer" to a vendor dependent on revenues this fiscal year.**
- **Vendor Fatigue causes poor response to repeated requests for cost estimates.**
- **The detailed design tends to lock in a particular vendor.**
- **Hence vendors "low-ball" estimates and increase price during real bidding process.**

Instrument Scientist communication is vital.

- **Initially, the AO project instrument scientist was in Montréal.**
- **Having a representative from the community was useful to gain Canadian support, and offered a broad perspective and useful expertise to the team.**
- **But the distance made good interaction with HIA difficult.**

Optical Designers

- **Optical designers can be wildly creative.**
- **Need a full time engineer to evaluate mechanical feasibility of optical designs in real time and keep designer on track.**

Design review documents

- **Microsoft Word does not work exactly as advertised.**
- **Applying a template, after the fact, to a large book, creates a lot of frustrating artifacts in section numbers, footers.**
- **We strongly recommend that you create a sample document, (not a 'template') in advance.**
- **From the beginning, all writers should type into a sample document.**
- **Publishing CDR book with a sample document went a lot smoother than for PDR.**

Functional Requirements Specifications

- **Paradox:**
- **A small specification doesn't cover enough of the issues.**
- **A detailed specification will not be read, understood, and remembered in its entirety by the whole team.**
- **Thus, system engineering review of specifications vs. design is an ongoing task.**

Mounting instruments to telescope

- **Builders have had to invent their own methods.**
- **Representative designs should be available to builders.**
- **Challenge is to accurately mount instrument without causing wear to Instrument Support Structure "cube".**

Control Software

- **EPICS does have some global advantages:**
- **Standard interface between observatory and instruments.**
- **Standard software engine to maintain within instruments.**
- **Good engineering access to internal signals for diagnostics -- This access, not ease of development, is EPICS' main advantage.**
- **It is free.**

EPICS is a PIG

- **"Something that costs nothing is worth every penny."**
- **Very steep learning curve**
- **Documentation non-existent or wrong**
  - learn entirely by trial and error
- **Hiring difficult - Rare skill in real world -**
- **Not convenient for graceful unattended recovery from problems, e.g. lead-screw jamming.**
- **Generic 'records' (device drivers) aren't really generic.**
- **Tools (e.g., CAPFAST etc.) very cumbersome**
  - difficult to create diagrams, and very difficult to interpret later

EPICS Recommendations

- **Use a very thin layer of EPICS to provide the interface protocol to the telescope, or among subsystems.**

- **Below this layer, do the real work in more conventional 'C' and VxWorks.**

- **Avoid State Notation Language (SNL) except for quick and dirty test stuff.**

- **Treat the CICS (core instrument control) system as a good structural example, not a fixed system that can be used with only some custom lower level rework.**

Test prototypes early.

- **Damn difficult to determine if a computer board is powerful enough from a data sheet, or simple benchmark.**
- **Altair has an unconventional single CPU 'reconstructor' -- instead of a farm of DSP's**
- **Fortunately, at PDR our review committee was skeptical and asked for a real demonstration long before CDR.**
- **If we had suggested an approach that they liked, whatever it was, we would not have bought boards until after CDR and would still be stumbling with manufacturers' problems.**

CPU benchmark lessons

- **Realistic test conditions are essential**
  - End-to-end data flow. E.g., from WFS CCD to DM.
- **Cache architecture crucial, not raw MegaFLOPS**
- **Beware manufacturers' claims**
  - Some shared-memory interface software arrived incomplete.
- **Some evaluation boards arrived broken.**
- **Low volume (Quantity 1) customers are often low priority**
  - find a vendor that is interested in your project
- **A board that is 'Available' may not be, and when you finally get it, it is unsuitable.**

Designing To Cost — Jim Oschmann – IGPO

Discussion Notes

- What is the difference between goals and requirements? Requirements are necessary deliverables while goals are not.
- More direct communication is required between IGPO, NGPOs, GSC, and IF.

- For 90% of all prototypes built, there is no value added.
- SCUBA lost 12-18 months because a prototype was built.

Design to Cost

Jim Oschmann
Gemini IGPO

Design to Cost overview

- **What is design to cost?**

Does it always involve trades in performance?

- **If it does involve a performance trade, at what level should it be considered?**

What is design to cost?

- **Serious consideration of costs at all levels through all phases of a project**
- **Original budgets should have included involvement from design engineers**
- **Relate budget flow down through detailed WBS**
- **Delegate responsibility for budgets consistent with the WBS to lowest level of design team**
- **Every one should know detailed cost targets for their area and overall cost target for the instrument**
- **Design trades should always include costs**
- **Raise problems early, trade across subsystems, simplify designs early**

Design to Cost
The Tie-in Project Management & Systems Engineering

- **What do you need first?**
  - Clearly prioritized science requirements
  - Detailed WBS & error budget
    - flow down of work organization and requirements, tied together
    - could be several 'budgets' such as image quality, etc
  - Good financial budgets tied to work breakdown structure and error budgets
  - Good communications between engineering and science teams
    - looking for simple solutions that meet high priority science requirements
    - resist the temptation to complicate designs (to give margin, or to meet goals)
    - "Better is the enemy of good enough"

Does it always involve a trade in performance?

- **No,**
  - but one must be willing to aggressively pursue trades and question specs where big financial gains can be made

If performance must be traded, at what level?

- **At all levels**
  - If trade is made at low level, use system level error budgets to asses impact of trade at the highest level
  - In many cases, low level changes of specs that seem significant, have little to no noticable impact on system level performance.
    - Include telescope, atmosphere, instrument, detector, processing
    - ie truly systems approach
- **Actively and aggressively work with science team and customer in trades that may impact performance**

Examples we were successful at

- ALTAIR Wavefront Sensor Optics
  - Major simplification at PDR
  - Eliminated majority of components
  - All large optics eliminated
  - One powered mirror eliminated
  - Major weight savings
- Alignment telescope handling equipment
  - Engineer did not consider cost at first (we did not tell him too)
  - Came up with $10,000 design
  - Asked to design something simple for a few hundred $
  - Final cost less than $200 (designed in a couple of hours)
  - Using stock materiel and commercial parts

Examples we did not gain from

- NIRI/GNIRS On Instrument WFS optics
  - may be offset with cryo gimbal complexity
  - this could have been simpler too
- GNIRS diamond turned optics
  - New technology developed to meet scatter spec that was too tight and did not affect performance at highest levels
  - Many existing vendors could have met needs without any development (at lower cost)
- GMOS optical design
  - May have been much simpler
  - **many elements and glass types should have been traded for cost savings early to see what is possible**
  - IR performance perceived to drive design
  - IR goals should 'come for free'

How to fully benefit in future

- **The earlier in a design cost is considered, the better**
  - With knowledge of the cost targets, problems will be brought up earlier to solve
  - Should be a major part of every review (internal and external)
  - Trades that may effect performance worked with Science team
    - Don't let performance alone dictate answers
  - Keeping systems simple usually equals lower cost, less risk, thus potentially more useful
    - Managers, key engineers, and science staff must think like systems engineers to balance trades properly
    - Constantly ask "what can I do to simplify this design?"

Cost trades at all levels

- **Design to cost understanding is needed at all levels**
  - Each designer/engineer should have cost targets in mind
  - If not at the most detailed level, then at a detailed subsystem level. Ideally, it should be tied to a detailed WBS that was used to originally plan and cost the work
  - Trades among subsystems aggressively sought to simplify, lower the risk, and lower the cost of the system
  - Management and Science teams as active participants in looking for cost savings throughout life of project
    - Involve customer
    - Question requirements that don't make sense
    - Question relative importance and total system performance - relate to total systems error budget

include telescope, atmosphere, detectors, etc

  - Keep in mind operational support costs
    - involve customer in details here!

Use existing designs

- **Look what others have done**
  - Was it successful?
  - Can it be simplified or improved with low risk?
  - Should be able to quantify costs easier
- **Commercial Off The Shelf - COTS**
  - Can commercial components be used or modified for use?
- **Must avoid the 'not invented here' syndrome**
  - Designing from 'clean sheet' gives FALSE impression of intellectual benefit
  - More time and money to spend on real problems that arise
  - Gain intellectual benefit from better 'systems' design
  - Produce more for less money and time

Active Management Support

- **Performance of individuals scored on consideration and accomplishments in controlling costs**
  - It is an individual responsibility at all levels
- **Encourage use of outside help where it may help**
  - "Make versus Buy" decisions
  - Use industry experience
  - Staff will gain more knowledge through working with more diverse groups and companies
  - True intellectual benefit comes from designing and building the best we can for the money
    - not from designing by yourself
    - Staff can learn more through effective use of contractors
    - Will result in *more* science for the money

Conclusions

- **Design to cost considered throughout life**
- **CoDR separate with cost targets as requirement**
  - not formally committed to full costs
  - serious effort to investigate feasibility and risks
  - if very high risks, propose intermediate steps or development
  - refine science and engineering requirements with detailed flowdown
  - consider major trades at this time, including engineering trades
  - identify contingency appropriate to completing the project beyond CDR
- **Balance engineering considerations from the beginning**
  - day 1 of beginning conceptual work

Conclusions

- **CDR is too late to consider solutions to cost overruns**
  - PDR is really pushing it
- **Commissioning part of process, but time and materials**
- **Communications within and external to the project is essential**

Round Table Discussion

Over-arching issue: How can we ensure that groups will want to build instruments for Gemini?

Topics

- Definition of ‘customer’
- Definition of ‘contingency’
- Overhead
- Incentives
- ‘Real’ project management
- Contract Procedures
- Software Issues
- International Collaborations

Who is the ‘customer’?

- Gemini should be treated as the customer even though they are not the end user.
- The GSC acts as the safety valve if scientific usefulness is thought to be compromised.
- Although Gemini is the overall project management team, they have been asked by the Partners to manage the project and therefore are the customer.
- Relationships with Gemini need to be symmetric so that all should understand.
- If Gemini is the customer, NGPO should be considered vendors with all associated formal interactions:
    - change orders
    - right to refuse requests

Definition of ‘contingency’

- Contingency should be used for estimation errors, unplanned events, rework, retest, etc.
- Unallocated contingency includes planning for risk factors and cost errors. Allocated contingency should be used to plan for unforeseen and uncontrollable events.
- What is the process for the use of contingency?
    - IGPO has a contingency budget – applied against changes in workscope.
    - Instrument Forum sets a contingency on a case-by-case basis – reserved for significant changes.
- Intended use of contingency would be reduced as a project progresses and is reassigned as phases are completed.
- Two kinds of contingency are needed:
    - Instrument Forum type – slow to get approval to use it, but necessary
    - project plan margin
- Budget and schedule contingency should be a functional tool used at the NGPO level.
- IF reviews are intended for significant instrument/science changes.

Standard Allowance for Overhead

- In Gemini collaborations, overhead can be an ineffective ‘rob from Peter to give to Paul’ type exercise.
- Providing for a 20% overhead allowance increases the instrument budget 20% which in turn increases NGPO contributions by 20%.
- Paying overhead is a ‘circular’ activity.
- Currently overheads are absorbed by NGPOs.
- Overhead structures are vastly different for each NGPO; therefore no direct overhead payment may be justifiable.
- Providing overhead may slow instrument building projects.

- Gemini can no longer bleed its instrument partners in the sole interest of getting instruments.
- A structure needs to be developed which is mutually beneficial to Gemini and NGPOs to develop an extended long-term instrument group.

Incentives

- Incentives could be provided based on meeting schedule and budget targets.
- What is more valuable to whom?
- Financial incentives could be provided in terms of workstations, software, shop equipment, funding for post-doc position of other staff, etc.
- Other incentives could be provided in terms of the success of the astronomy program.

- Recognition can go a long way – satisfying for engineers?
- Some partners don’t feel as members of the Gemini team.
- ‘Customer’ needs to recognize ‘vendors’.
- Recognition should lead to the ticket to build next generation instruments.
- Program is cash limited
  - contingency
  - overhead
  - incentives

- Fixed price, not capped, contracts should be negotiated at CDR.
- NGPOs could keep any unspent money if a project came in under budget.

‘Real’ Project Management

- ‘Real’ project management does not mean putting a plan together using MS Project.
- It is a proactive activity to ensure smooth flow of a project:
  - catch problems
  - review effort
  - make sure targets are in sight
  - track budget

    - track schedule
    - track objectives, goals, and requirements
    - track progress
- Looking at the ‘big picture’ is a continuous process:
    - quarterback the workload
    - determine the effects of change to the delivery
    - determine the effects of trades
    - determine the critical path and the reasons that a path is the critical one

- Balancing ‘mind-numbing’ project management vs. Retaining staff
- Highlight ‘paperwork’ as opportunity to provide positive exposure – illustrate the good points/issues.
- Successful project managers can acquire the ‘% of task complete’ figures by holding short routine meetings and talking to staff.
- There needs to be a belief that efforts are bearing fruit – demonstrations should be made or examples provided.
- Minimize the amount of paperwork staff need to fill out – hire someone who likes the project management related duties (they do exist).

- ‘Real’ project management involves in part:
    - walking around
    - talking to staff
    - holding meetings
    - colouring bar charts
    - involving staff
    - paying attention

Streamlining Contract Procedures

- Currently, turnaround times on contract drafts are long, and dreaded by all.
- Use of standard contracts may alleviate current problems – make amendments when/where needed.
- One effective method of negotiating contracts has been to get all authorized players to take part in a videoconference and hammer out the terms of an agreement.
- Negotiating workscopes should be carried out by identifying major aspects and components of a project, create a draft version, and refining the details (as a group) with all the major players present.

Software Issues

- IGPO is working on an initiative to allocate a group of several people who will be dedicated to instrument software issues (1 FTE) to streamline EPICS issues (within 6 months to 1 year).
- Revised CICS (CICS2) to provide a standard for instrument development.
- Prepare a proposal to create a working group for instrumentation software issues.

International Collaborations

- How should future international collaborations be dealt with?
  - Consider entering sub-contracting arrangements.
  - Identify roles upfront.
  - Specify contractual obligations.
  - Insure shared risk issues are fully understood.
  - There is an importance to insure all partners feel like partners.
- There are many different views of partnership:
  - intellectual collaborations
  - working partners
  - shared work partners
  - team members

Common Threads

Project Management Issues

- Effective project management is essential to the success of an instrumentation project.
- Project Management should be perceived as a simple, effective, rewarding exercise.
- ‘Wallpaper’ project management isn’t effective or useful.
- More effective communication is needed, but how?
    - meetings
    - workgroups
    - staff involvement

Current project management problems:
- Lack of understanding of definition of and implementation of proper project management.
- Uniform and consistent underestimation of budget and schedule.

Instrumentation Issues

- Given the ‘half-life’ of instruments and economic effects such as inflation, project teams need to move faster through the design stages, but resources are limited.

- Software inconsistencies are posing problems on all instrument projects.
- It isn’t enough that software works, but that it is also effective.
- Important software issues:
    - large EPICS learning curve
    - staffing issues due to EPICS

Contract Issues

- ‘Fast tracking’ contract negotiations may allow for faster instrumentation design phases.

- Contract negotiations are seen as a dreaded process, mainly due to the perceived time requirements on time strapped resources.
- Contracts should be negotiated in stages and include estimate contingencies.
    - Ex. Negotiate fixed fee contracts to CoDR with a ± 25% estimate allowance on the final budget and/or schedule. The estimate would become more stringent as new contracts are negotiated at different design stages.