Project Science

From Small Science to Big Science

Gary Sanders, TMT Project

Project Science Workshop

Fort Lauderdale, November 2010

The Project "near death experience"

- **Too many large scientific projects get into trouble**
  - **Trouble is diagnosed at vulnerable times**
  - **Projects are frequently reorganized**
  - **Some projects are canceled or they fail**
- **The "near death experience" lurks**
  - **"small" science approach taken too far**
  - **Institutional setting mismatched**
  - **…**

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A frequent pattern – "coaching" scientific teams

- **Scientific team initiates a project concept**
- **External Review**
- **Cry**
- **Coach**
- **Review**
- **Cry**
- **Coach**
- **Fire and/or Hire**
- **Reorganize**
- **Review**
- **…**

the near-death experience

- **There has to be a better way**
  - **Lessons learned**
  - **Interactional expertise**
  - **…**

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Some Responses

- **Value project success as well as scientific and technical success**
  - **Are our agencies and laboratories as strong in project expertise as in science?**
- **Spread case-based experience of scientist/managers to those in emerging projects**
  - **Percolate expertise and values**
- **Make the scientist-specific cultural setting visible**
- **Make the project-specific cultural setting visible**
- **Teach nuts and bolts of managing projects**
- **Turn on project mindset as early as possible in a new effort**

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Who is it for?

- **mid-career scientists entering big projects**
- **first-time managers of big scientific projects**
- **project oversight officials**
- **…**

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Goals for this workshop

- Cover a great deal of experience-based material in a short time
- Add a cultural view to the traditional scientist's perspective and experiment with this
- Learn lessons for next time
- Study each other, learn from each other

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What I will cover at this workshop

- From Small Science to Big Science
  - Cultural and social setting of big science
- Planning for Performance Measurement
  - Overview of how to organize and manage an “ideal” scientific project
- Selected Details
- Complex Projects
  - Collaborations, composite operating/project organizations, multiple funding sources, global projects, bottom-up co-laboratories…

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The First Two Presentations

- **The scientist's cultural setting**
- **Small vs. Big science**
- **The "Linear" Project**
  - **Stages in a Project**
  - **The Baseline**
  - **The Design Process**
  - **Work Breakdown Structure**
  - **Project Organization**
  - **Management Plan**
  - **Cost Estimate and Risk Analysis**
  - **Schedule Development**
  - **Performance Measurement**

How to make the "never been done before" deterministic and routine

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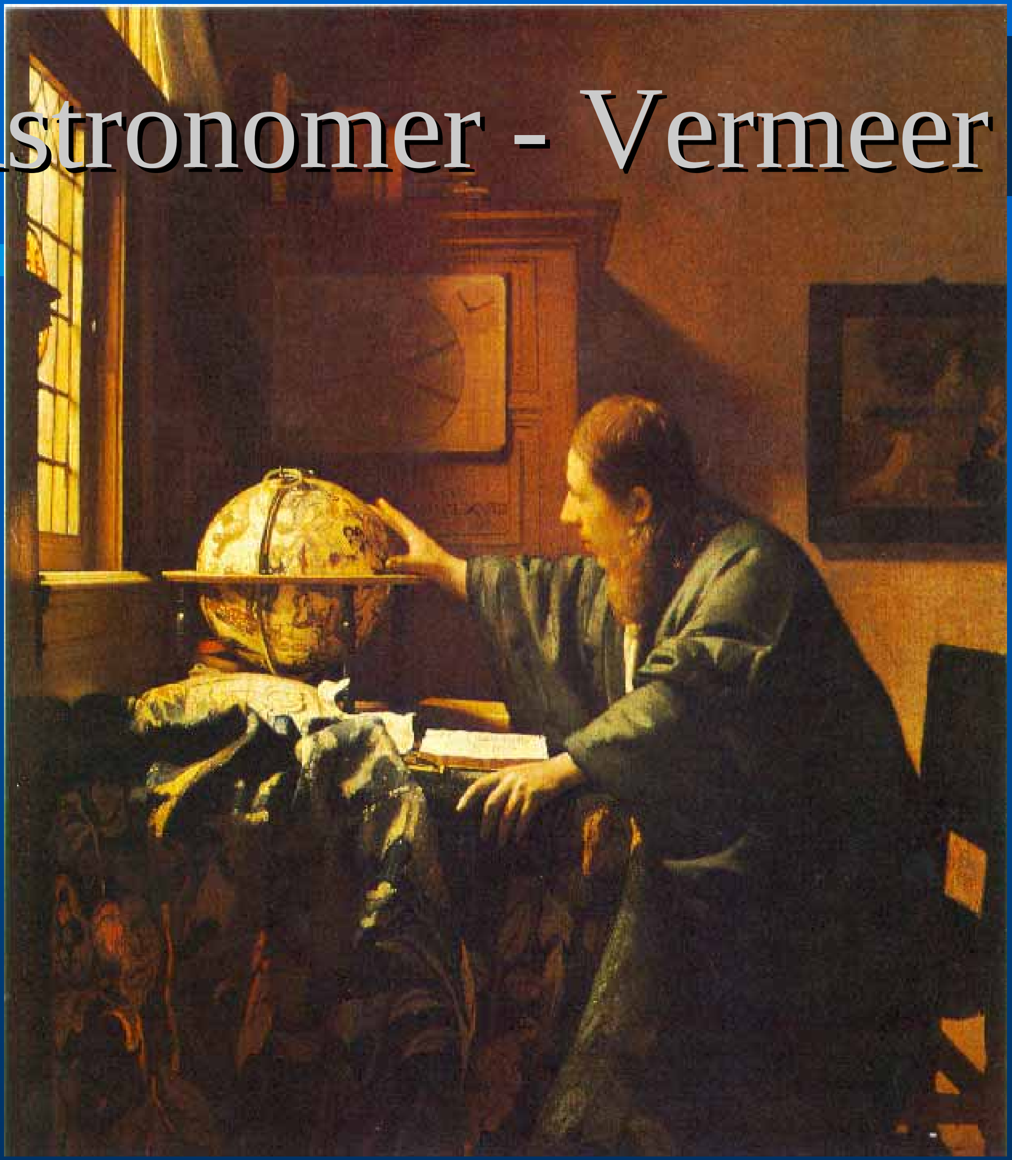
The Astronomer - Vermeer



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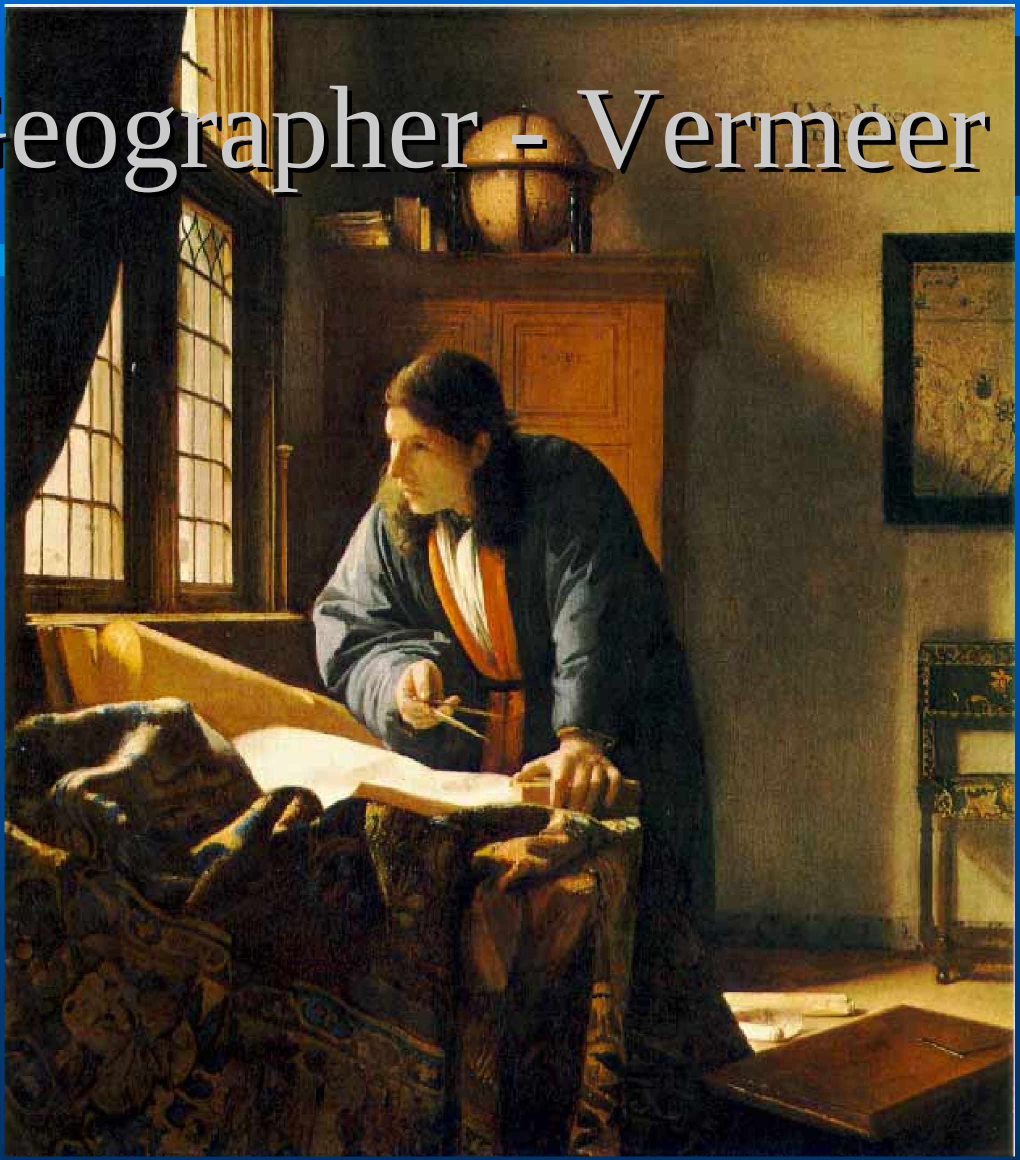
The Geographer - Vermeer



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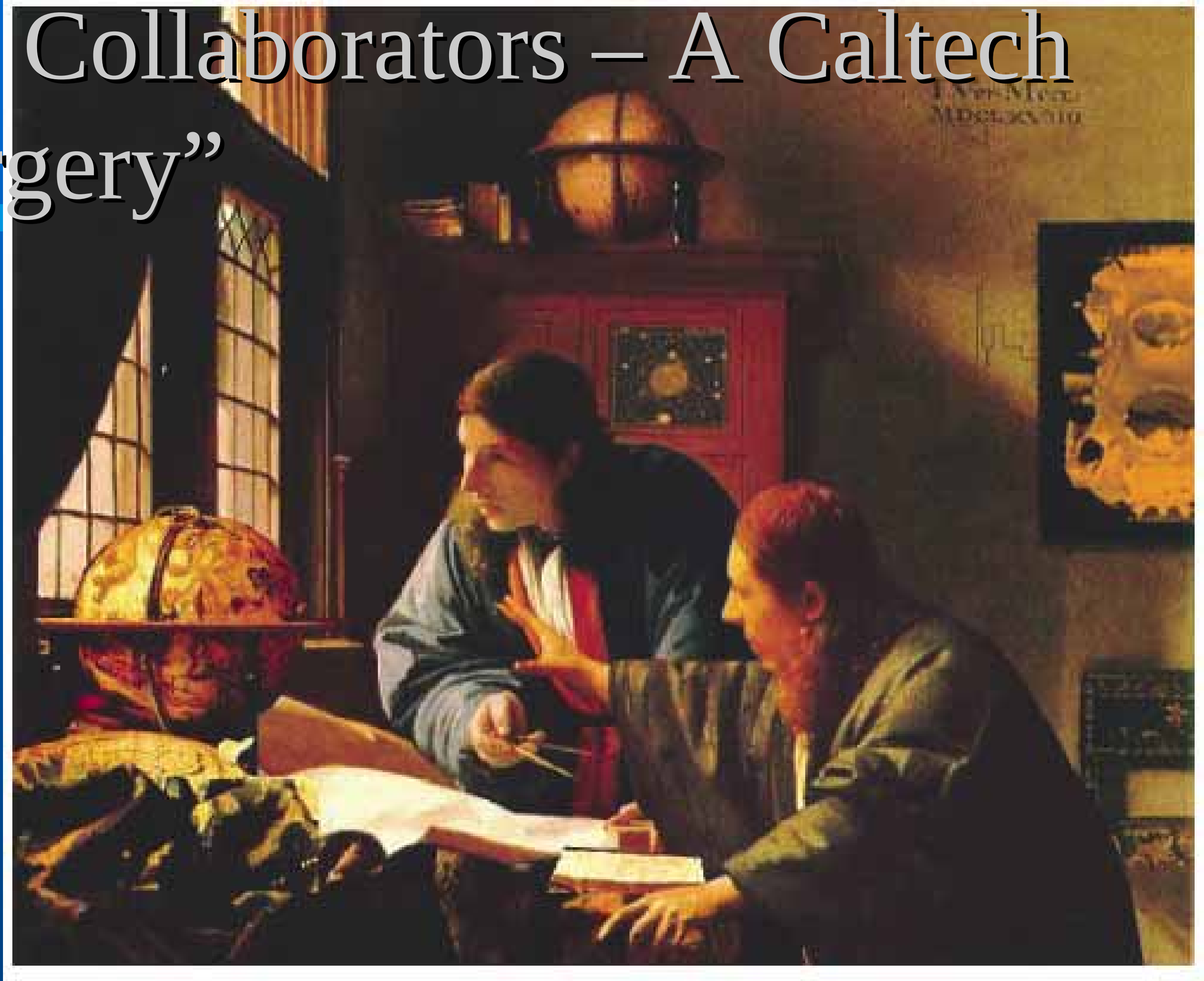
The Collaborators – A Caltech "forgery"



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UBIQUITOUS EXPERTISES

DISPOSITIONS				Interactive Ability Reflective Ability	
SPECIALIST	*UBIQUITOUS TACIT KNOWLEDGE*			*SPECIALIST TACIT KNOWLEDGE*	
EXPERTISES	Beer-mat Knowledge	Popular Understanding	Primary Source Knowledge	Interactional Expertise	Contributory Expertise
				Polimorphic *Mimeomorphic*	
META-	*EXTERNAL (Transmuted expertises)*		*INTERNAL (Non-transmuted expertises)*		
EXPERTISES	Ubiquitous Discrimination	Local Discrimination	Technical Connoisseurship	Downward Discrimination	Referred Expertise
META-CRITERIA	Credentials		Experience	Track-Record	

"Expertises" – Harry Collins

- **Contributory expertise – the knowledge that enables a participant to advance a field**
- **Interactional expertise – knowledge sufficient to understand the subject matter of a field and to support communicating intelligently with contributory experts in the field**
- **Referred expertise – Expertise of a contributory or interactional nature in one field that is applied usefully in a new field**

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Interacting in little circles

Contributory expertise

Lone researcher

Tacit knowledge

Community and shared history

Expertise narrowly defined

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Collaborators

Lone researcher 1
Tacit knowledge
Community and shared history
Expertise narrowly defined

Lone researcher 2
Tacit knowledge
Community and shared history
Expertise narrowly defined

Contributory expertise

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Projects

Lone Project Manager
Tacit knowledge
Community and shared history
Expertise narrowly defined

Lone researcher
Tacit knowledge
Community and shared history
Expertise narrowly defined

Lone engineer
Tacit knowledge
Community and shared history
Expertise narrowly defined

Contributory expertise

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Project Science as a culture

- **Theoretical scientists**
- **Experimental scientists**
- **Project scientists**

Three distinct cultures and temperaments

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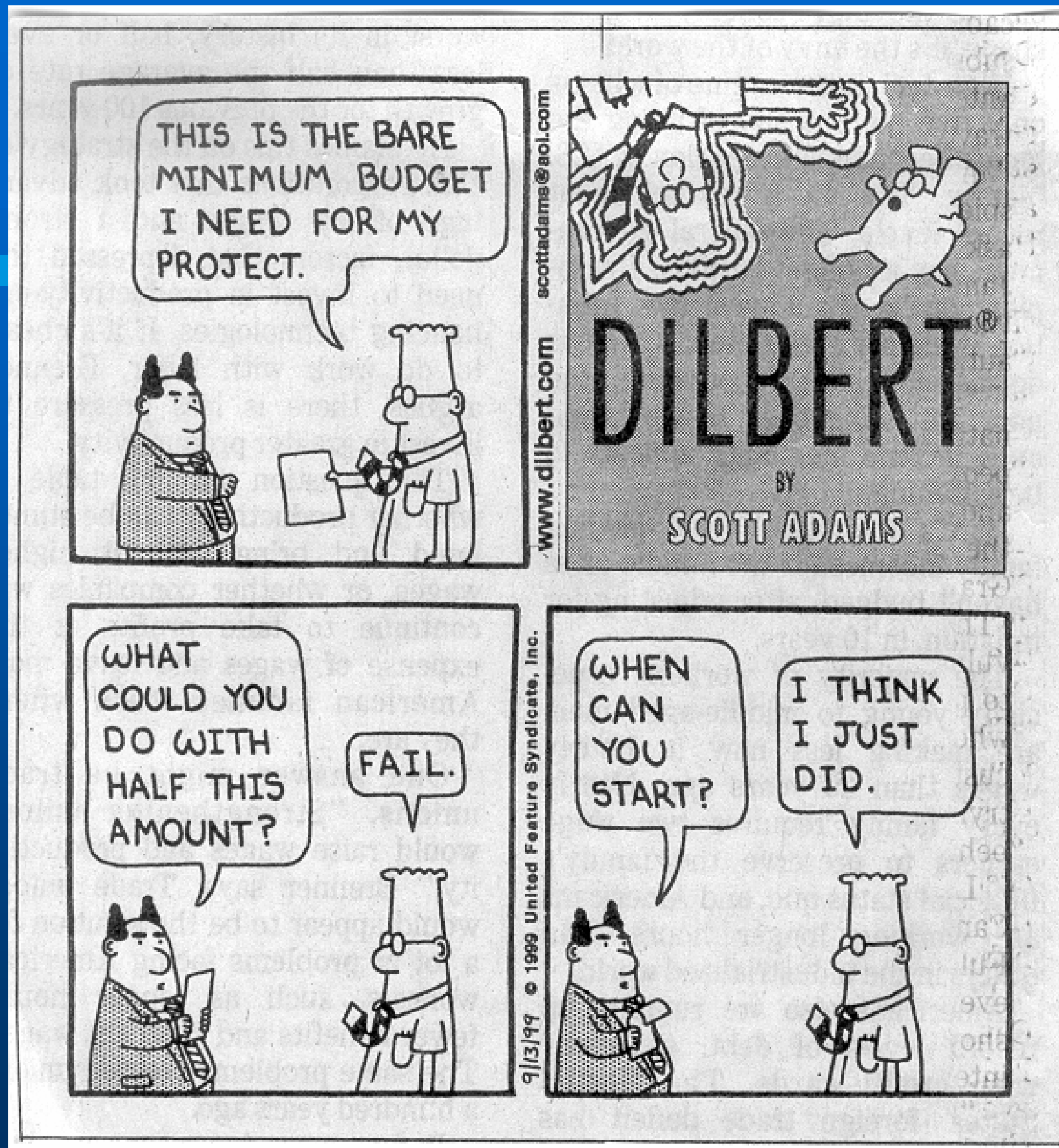

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Project Management and Management of Operating Organizations

- **Project management**
- **Operating management**

Two distinct cultures, temperaments, and management goals

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The Project Mindset

The essentials of a project

"See first that the design is wise and just: that ascertained, pursue it resolutely; do not for one repulse forego the purpose that you resolved to effect."

William Shakespeare ?

1. system design
2. siege planning
3. robust execution

Paul Dinsmore, Human Factors in Project Management

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The project manager's motto – the project mindset

"le mieux est l'ennemi du bien."
Voltaire, 1764

"Il meglio e l'inimico del bene"
– Boccacchio, 14th century

"the better is the enemy of the good enough"

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Educating and Selecting the "Small Science" Contributor

The training and selecting of scientists

- **Undergraduate study – reading and problem sets**
  - **Selects productive problem solvers**
- **Graduate study – Apprentice research under an advisor**
  - **Absorb the advisor's techniques and values**
- **Early postdoctoral career – Independent contributor to research**
  - **Show independence, innovation, creativity, analytical and technical mastery, focus, teaming in small teams**
- **Midcareer – Mentor in research**
  - **Confidence, mastery, emergence as a leader in a research field, strong focus, tenacious, competitive, seeker of "truth"**

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Work-motivation of scientists

- **Among the most stable of work-motivations throughout one's career* are the need for:**
  - **Achievement**
  - **Affiliation**
  - **Power**
- **The selection process for scientists prefers achievement**
- **Big science requires teams and members who value affiliation and power**

* McClelland,D.,Motives, Personality and Society, New York: Praeger 1984

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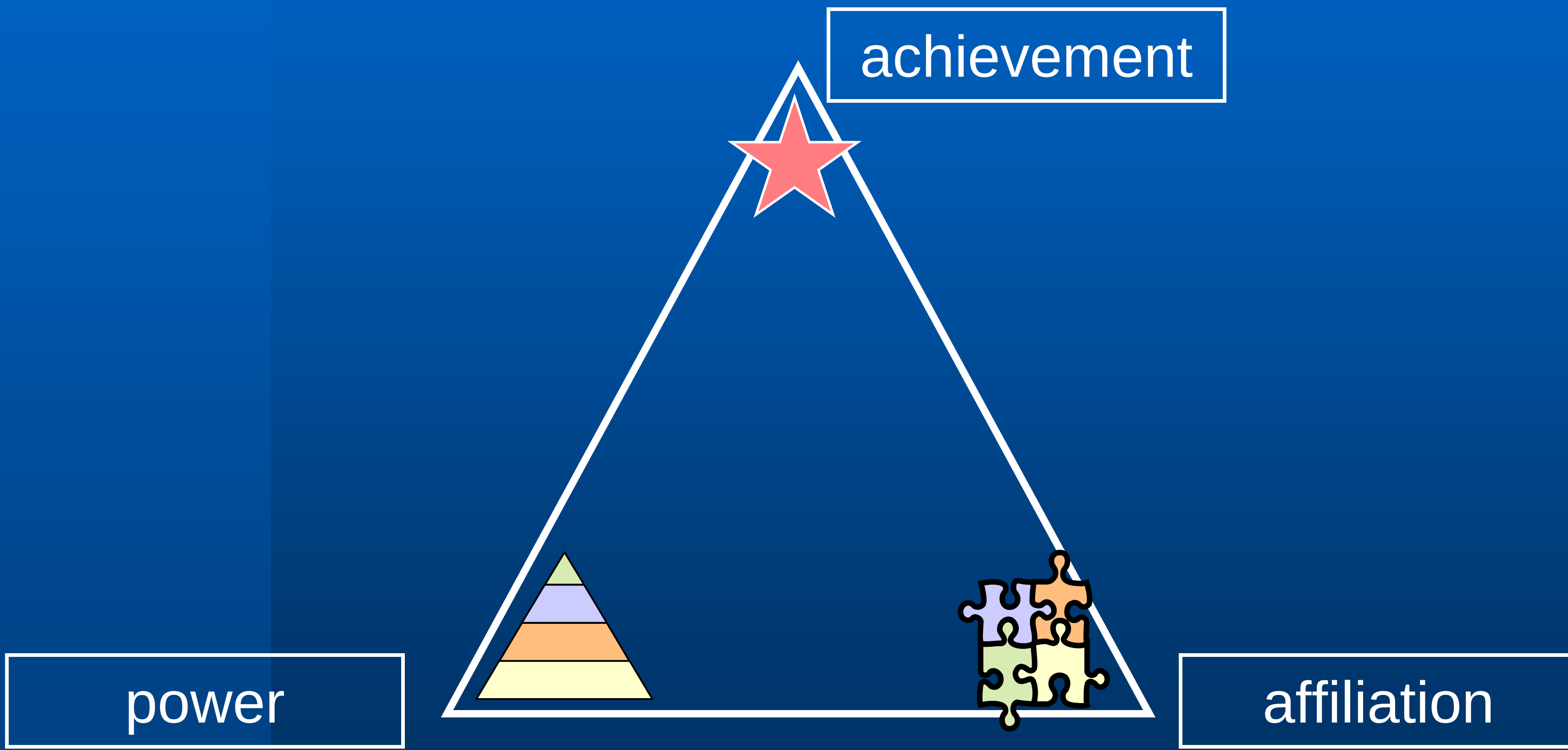
Work motivation mapping



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Small vs. Big Science

Los Alamos - Project Y

From the left, Norris Bradbury, J. Robert Oppenheimer (second row), John Manley, Richard Feyman (second row), Enrico Fermi and J.M.B. Kellog at an early laboratory colloquium.

"In early 1943, John Manley, the experimental physicist from the University of Illinois on assignment to the Metallurgical Laboratory of the University of Chicago, visited University of California theoretical physicist J. Robert Oppenheimer, whom he had been assisting with plans for the new laboratory at Los Alamos. He had "bugged Oppie for I don't know how many months about an organization chart - who was going to be responsible for this and who was going to be responsible for that. But one day in January, I climbed to the top floor of LeConte Hall where Robert had his office and pushed open the door. Ed Condon (the Westinghouse physicist whom Oppenheimer had chosen as his deputy director) happened to be in there with him at the moment, but Oppie practically threw a piece of paper at me as I came in the door and said, 'Here's your damn organization chart,' " Manley recounted."

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Small Science vs. Big Science

Attribute	Small Science	Big Science
Decisions made by	scientists, creators, inventors	managers, directors, delegated
Design flexibility	flexible, creative	fixed, baselined
Fabricated by	in-house craftwork, "make"	industrial approach, "buy"
Team composition	predominantly scientists	scientists, engineers, accountants, PMs
Visibility of project	private	public
Project process	opaque	transparent
Success defined by	scientists, creators, inventors, peers	managers, reviewers, sponsors, peers

From discussions with Harry Collins

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"Expertises" of a Project Manager

- **In the project's subject matter field**
  - **Contributory or**
  - **Interactional**
- **In the field of project management**
  - **Contributory and**
  - **Referred**

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Big science is public

- Everything about the conduct of big science must be transparent to the public
- This is an ethical imperative
  - You are consuming resources that could make a difference to:
    - The public
    - Other recipients of the private support
    - Other scientific opportunities
- Your project's resources are not an entitlement
- You must be prepared to be on "60 Minutes"

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Big science – Big cultural gap

- **The selection process that yields excellent mid-career scientists provides little preparation for this**
- **Mismatch of normal scientific research culture and the culture of project management**
- **Early project stumbles lead to trouble, reorganization, delay, poor reputation of scientific projects**
- **Experience and expertise in managing large ongoing scientific labs/teams does not bridge this gap**
  - **Operating management and project management are distinctly different fields**

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Big Science vs. Small Science

- **Nothing I say about the limitations of the culture and methods of small science should be taken as deprecating.**
- **I would change little about how small science is practiced. It is a culture that seeks scientific discovery and truth.**
- **The two scales of scientific avctivity must coexist.**

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The project manager's challenge in bridging/combining cultures

- **Appropriately emphasize the small science culture and big science culture in different amounts in**
  - **Design – small science leads**
  - **Planning – big science leads**
  - **Execution – big science leads**
    - **Repair of the project – small science crucial**
  - **Transition to science usage – transition towards small science**

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Big science approach

- **Create planned project**
  - **Convince yourself that you can do the project this way**
    - **Own the plan**
    - **Use the plan**
    - **Perfect/adapt/repair the plan in a highly disciplined manner**
  - **Develop confidence of sponsor**
    - **Planned project approach is not just a defensive shield against sponsor intrusion**
    - **Sponsor is an ongoing partner**

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The "Linear" Project

The "Linear" Project: An Ideal

- **Before we can create and manage a real world project we must be able to isolate the "ideal" project inside the real project**
- **What are the identifying features of the ideal project?**
  - **The project that can be managed in a straightforward "linear" manner**

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The “Linear” Project

Executing the project consists solely of carrying out a well defined plan

- **Project goals and requirements are stable**
- **Sponsor support and funding are stable**
- **Managing institutions do not confuse the goal of project success with their other goals**
- **Resources are matched to project**
- **Resources are really controlled in one project office**
- **Project team owns the plan**

The result is that the major risks are technical

- **Remaining risks are inexperience and human behavior**

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Stages In A Project

From an experiment to a project…

Distinct stages in a project…

- Definition to Reference Design
- Reference Design to Baseline Definition
- …to Final Design and Commitment
- … to Industrialization

Manage obligations

- Execution and Performance Measurement

Manage costs

- Integration and Plan to Completion
- Endgame

"broke and done on the same day"

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Project phases

- Conceptual - proposal, R&D
- Planning - defining baseline
- Design - requirements,prelim.,final
- Industrialization - obligate
- Performance - earn value, quality
- Integration
- End Game - done & broke together

this
talk

Project
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Definition to Reference Design

Definition to Reference Design

- **Define scientific question(s)**
- **Define science requirements**
- **Develop informal conceptual design**
- **Define and initiate needed R&D**
- **Define technology options***
- **Produce traditional small science experiment proposal**
- **Define “reference design” ***

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TMT example slides follow

Major Steps To Date (from CoDr talk)

- **Adopted science requirements from Science Advisory Committee (SAC)**
- **Reference Design**
  - **Defined reference technical requirements**
  - **Developed single reference design from 3 precursor designs**
  - **Defined reference adaptive optics (AO) and instrument architecture**
- **Parallel conceptual or feasibility design studies carried out by**
  - **Industrial partners**
  - **North American instrument community**
  - **TMT Project team**
- **TMT Project carried out**
  - **concurrent system engineering**
  - **site selection studies**

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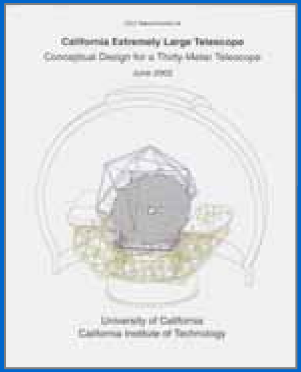
Unifying the Precursor Studies

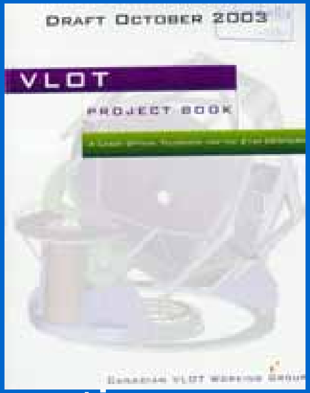
TMT follows from a careful consideration of three, independently-conceived & independently-reviewed, point designs representing ≈$6M total effort

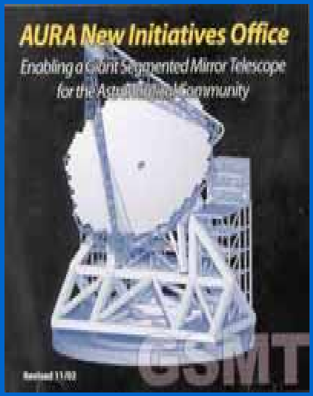
CELT (UC+Caltech)

VLOT (Canada)

GSMT (NOAO/Gemini)



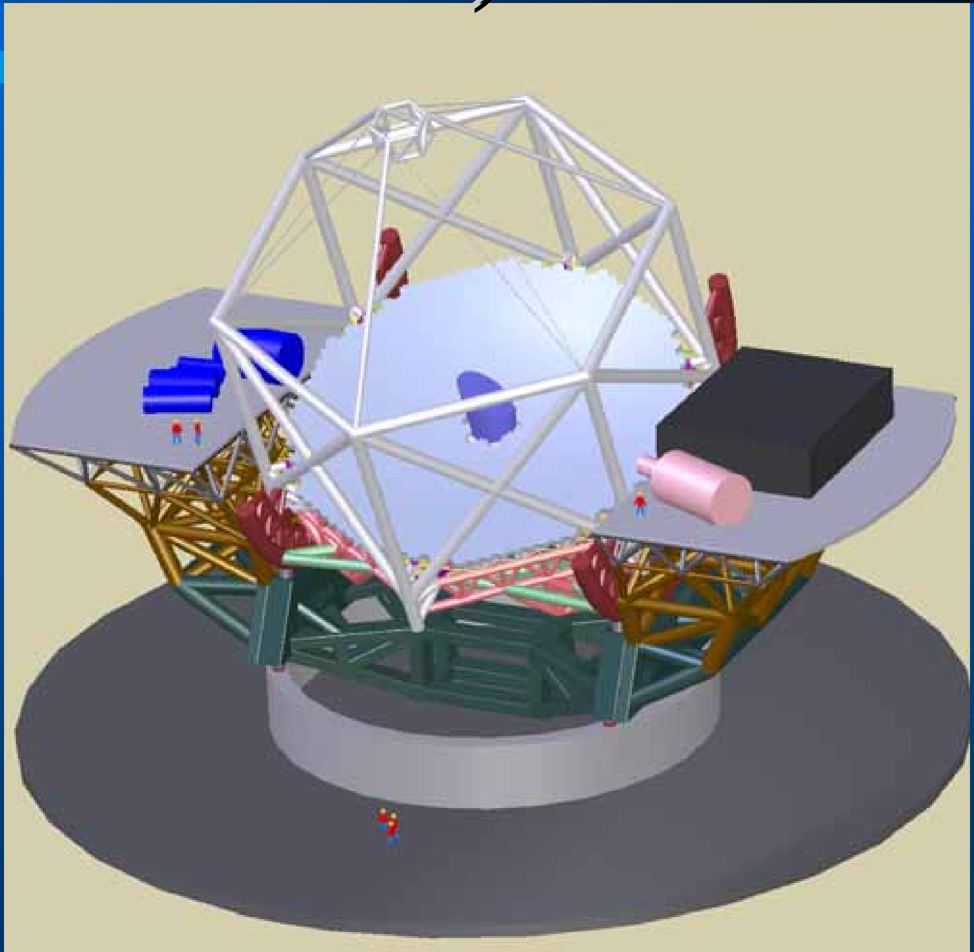




- – Broad exploration of technical options
- – Positive reviews by outside reviewers
- – Diverse approaches addressed similar requirements
- – June - September 2004 "16 week exercise" carried out competing trade studies
- – **Single reference design was established by TMT**

TMT Reference Design (established November 2004)

- **30m filled aperture, highly segmented**
- **Aplanatic Gregorian (AG) two mirror telescope**
- **f/1 primary**
- **f/15 final focus**
- **Field of view 20 arcmin**
- **Elevation axis in front of the primary**
- **Wavelength coverage 0.31 – 28 µm**
- **Operational zenith angle range 1° thru 65°**
- **Conventional and adaptive secondary mirrors to be interchanged**
- **No telescope baffles**
- **AO system requirements and architecture defined**
- **First generation instrument requirements defined**



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Reference Design to Baseline Definition

Reference Design to Baseline Definition

- Turn a defined experiment into a defined project
- The Baseline Definition is the basis for comprehensive organization of the
  - work to be performed
  - technical scope of product
  - cost and resource estimates
  - workplan and schedule
  - risk management plan

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The baseline...

- **Scientific requirements are defined and fixed**
- **Technical requirements meet the scientific requirements and are fixed**
- **Project deliverable is defined in a conceptual design**
- **Subsystems are defined**
  - **interfaces are defined**
- **Work Breakdown Structure (WBS) defines all work to be performed in the project including delivery of each subsystem and their integration**

...The baseline

- Costs are estimated at the lowest level in the WBS
- Schedule is developed following the WBS
- Costs and other resources are integrated with the schedule to define the value of each scheduled activity, and a profile of obligations and costs
- Risks are assessed at the cost estimate level in the WBS and a contingency pool of funds are defined for project-wide management of risks
- Basis for performance measurement is established

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When to “baseline”?

- **On day 1 with pencil sketch?**
- **…**
- **After conceptual reference design defined?**
- **…**
- **When sponsor makes full commitment?**
- **…**
- **At Final Design Review?**
- **…**
- **When “as-built” drawings are completed?**

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When to “baseline”?

- **This question is very much misunderstood**
- **At some point the sponsor accepts a baseline definition as a solemn promise**
  - **Project definition frozen too early can be source of great tension when normal project development process leads to prudent evolution**
  - **Recent tendency is to delay freezing formal baseline as much as possible so that adopted formal baseline can be stable**
- **This leads to irresponsible softness in project team commitment to the reference design**
  - **“After all, we aren’t baselined yet, so…”**

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Reference Design to Baseline Definition

- **Put reference design under early configuration control as interim baseline**
  - **You are trying to grow a culture of disciplined work that fosters commitment to timely decisions**
    - **Team commits to "strawman"**
    - **Team learns process of orderly change**
    - **Team learns that work can now move forward**
    - **Team learns hierarchy of technology options and design choices**
      - **Baseline choice with fallback option and decision date**
      - **Equal options with decision date**
      - **Firm baseline choice with no option**
    - **Sponsor must recognize what this is**

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The design process

- Design Requirements
  - Including Conceptual Design
- Preliminary Design
- Final Design
- These phases structure the design process
- Deliverables of each phase structure the workplan and schedule

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Design Requirements phase

- **Define science requirements**
- **Define technical design requirements that meet the science requirements**
- **Develop an illustrative conceptual design that meets the design requirements**
- **Carry out needed R&D**
- **Prepare a Design Requirements Document including a companion Conceptual Design Document**
  - **Conceptual design is an illustrative design that meets the design requirements**
- **Satisfy a thorough review (DRR) of these deliverables that enables progression to next phase**

Preliminary Design phase

- **Based upon the products of the previous phase, carry out sufficient R&D and design to fully define the design to be built, in sufficient detail to demonstrate that the Design Requirements are met and that all significant design choices are made**
  - **Include specification of processes in fabrication**
  - **Include all needed analytical calculations**
  - **May include production of prototypes**
  - **This design will not be sufficient to define the fabrication**
- **Prepare a Preliminary Design Document and an updated Design Requirements Document**
- **Satisfy a thorough review (PDR) of these deliverables that enables progression to next phase**

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Final Design phase

- **Based upon the products of the previous phase, carry out sufficient R&D and design to fully define the design to be built in sufficient detail to support production fabrication**
  - **Include specification of processes in final fabrication**
  - **Include all needed analytical calculations**
  - **All relevant R&D results available and incorporated**
  - **May include production of "first articles" with testing**
  - **This design will be fully sufficient to define the fabrication**
- **Prepare a Final Design Document and an updated Design Requirements Document**
- **Satisfy a thorough review (FDR) of these deliverables that enables progression to production fabrication**

bend metal

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The design process and system engineering

- **The design reviews at the DRR, PDR and FDR stages are to be separately carried out for the overall system and for each of the subsystems**
  - **Definition of interfaces between subsystems to be included in each review**
- **This structures the system engineering**
  - **Apportionment of noise budgets, tolerances, contributions to performance requirements are thus included in this process**
  - **Interface definition**

What we have covered

- **The scientist's cultural setting**
- **Small vs. Big science**
- **The "Linear" Project**
  - **Stages in a Project**
  - **The Baseline**
  - **The Design Process**
  - **Work Breakdown Structure**
  - **Project Organization**
  - **Management Plan**
  - **Cost Estimate and Risk Analysis**
  - **Schedule Development**
  - **Performance Measurement**

From small science to big science

To a baselined project ready to build

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