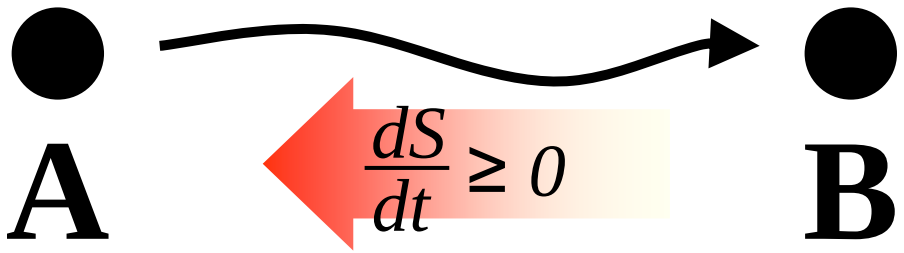
Preconstruction Planning for Large Science Infrastructure Projects

A comparative analysis of practices and challenges at DOE, NASA and NSF



William L Miller, Ph.D.
AAAS S&T Policy Fellow
NSF Large Facilities Office

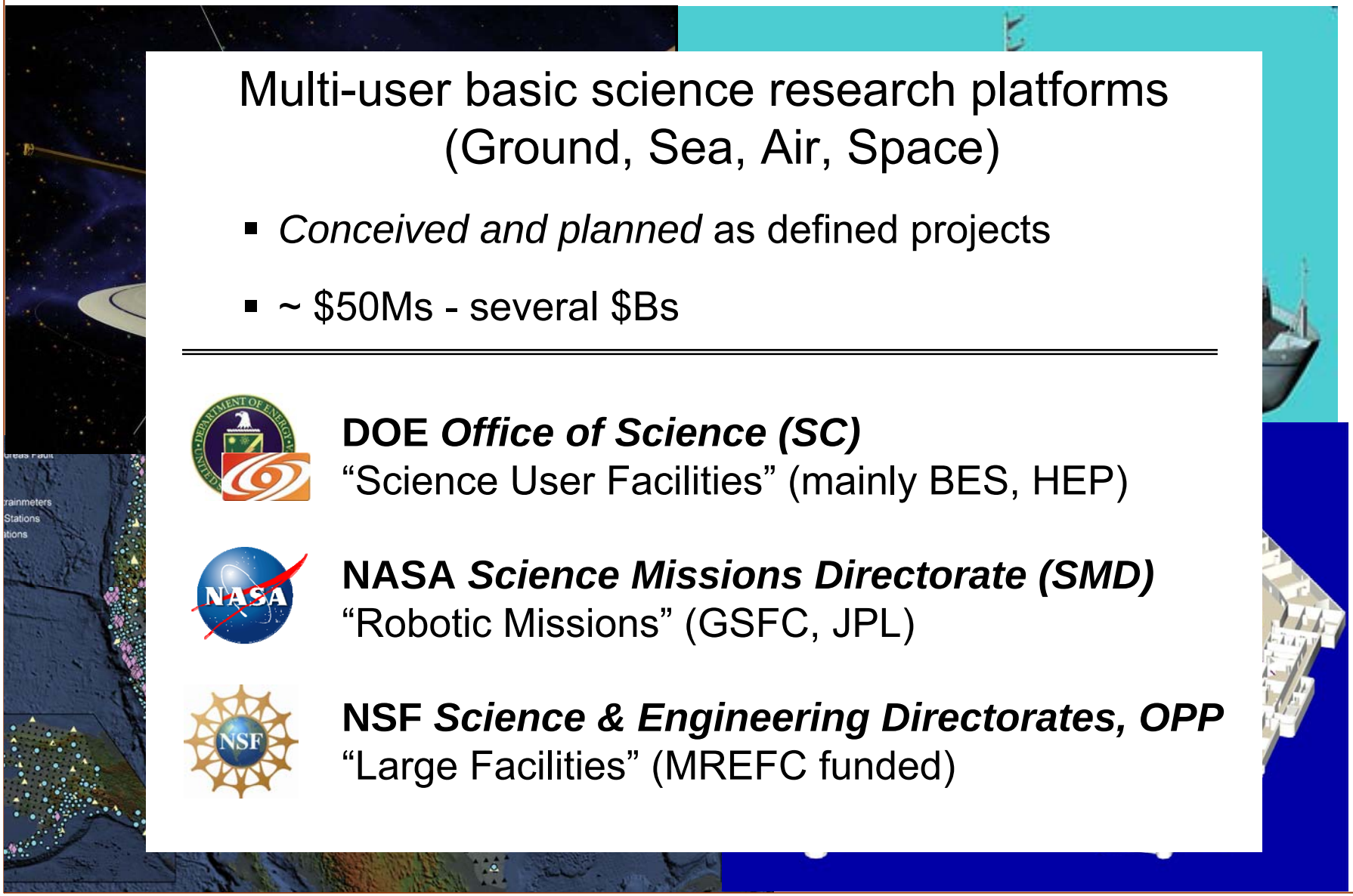
Year-long study (started mid-September 2008)

- **Objectives:**
  - Compare processes and practices for **preconstruction planning** of **large science infrastructure projects**, at NSF, NASA and DOE.
  - Identify similarities, differences, best practices, challenges, outcomes
  - Indications for improvements to NSF process, and for partnering.
- **Approach:**
  - Technical: Examine official policy guidelines and manuals, internal and external studies and analyses (e.g. NAS, RAND, GAO etc.)
  - "Look under the hood": Interview stakeholders; attend facility design reviews, management workshops, LSS Subcommittee meetings.
- **Output:**
  - Provide a report of practical utility to federal science facility stakeholders at NSF and beyond.

Today's talk

- Scope definition
- Agency comparisons
  - Structural factors
  - Processes
  - Governance & oversight
  - Funding, cost estimation, acquisition start
  - Performance
- How can NSF improve its process?

Scope definition: Projects and Organizations



Multi-user basic science research platforms
(Ground, Sea, Air, Space)

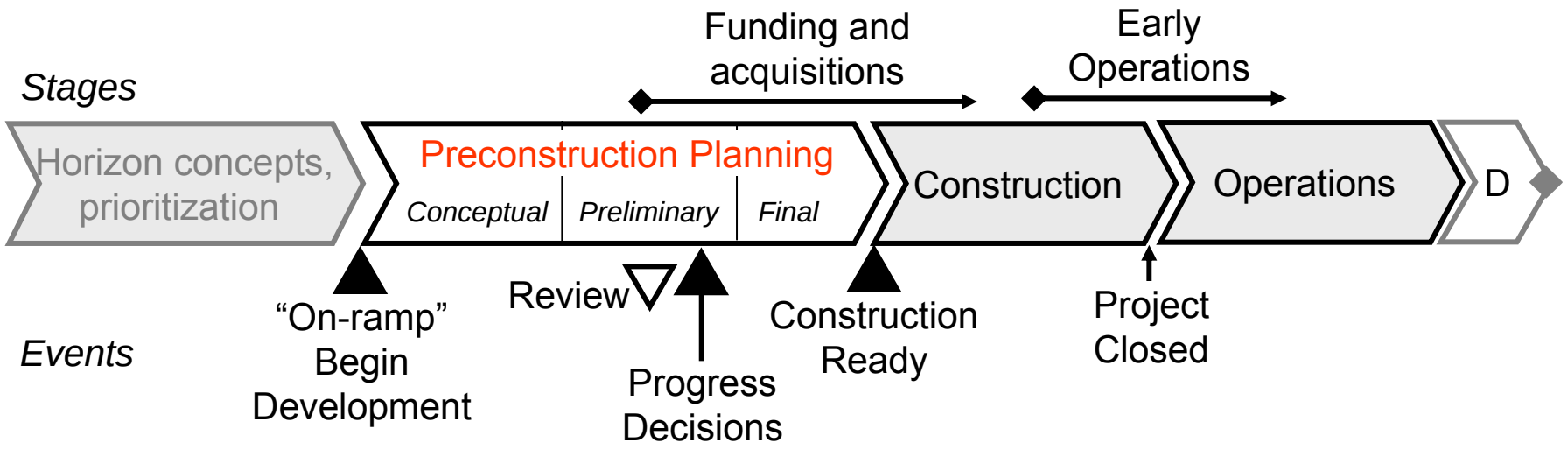
- *Conceived and planned* as defined projects
- ~ $50Ms - several $Bs

DOE *Office of Science (SC)*
"Science User Facilities" (mainly BES, HEP)

NASA *Science Missions Directorate (SMD)*
"Robotic Missions" (GSFC, JPL)

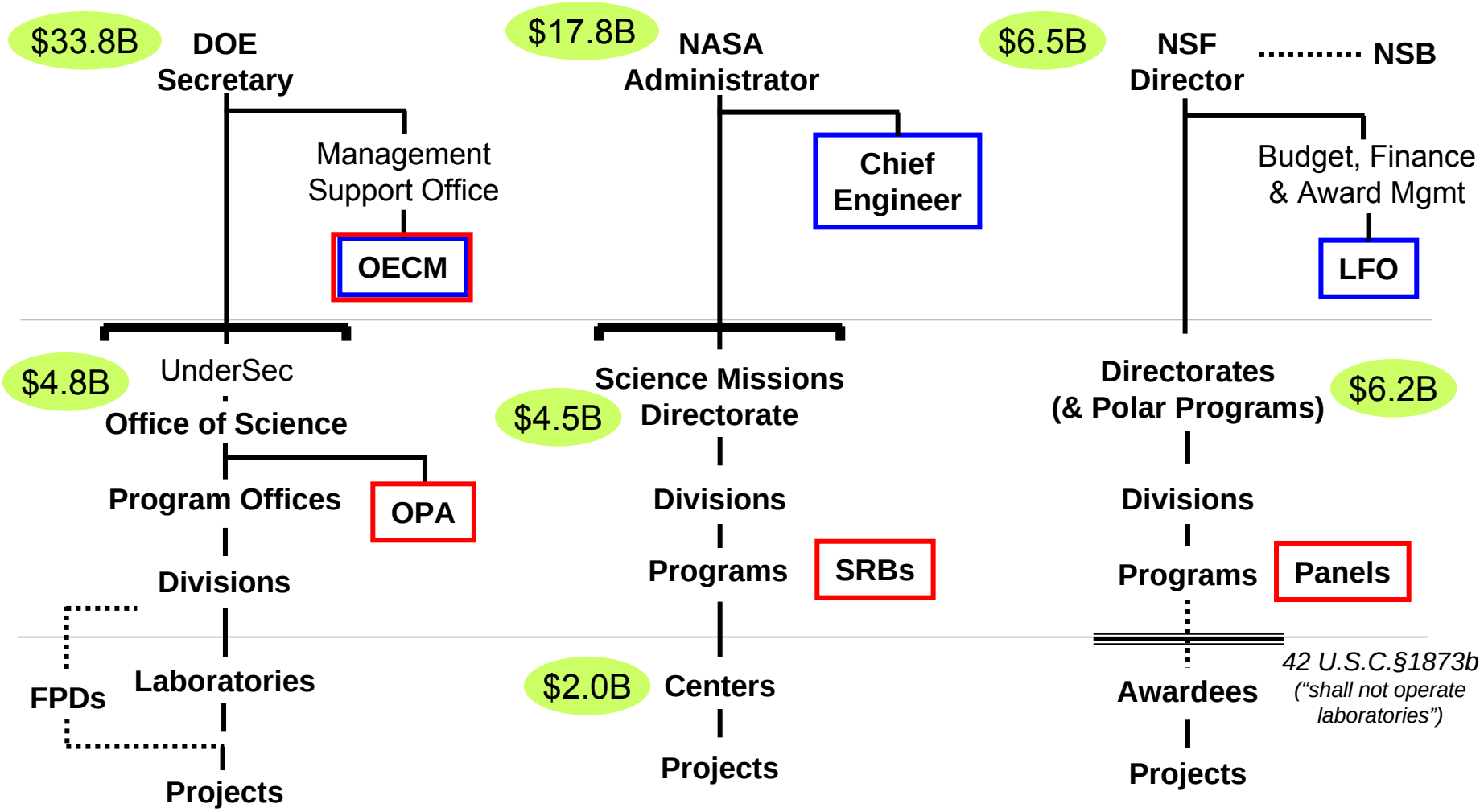
NSF *Science & Engineering Directorates, OPP*
"Large Facilities" (MREFC funded)

Scope Definition: Preconstruction planning



Terminology	• Called many things (definition, formulation, front-end planning…) • Industry "pre-project" (pre-bid) planning (*by owner*) vs. post-award "pre-construction planning" (*by builder*) are lumped: often not distinguishable for federal projects.
Activities	• *Plan:* Management/governance plans, WBS → assemble project team • *Design:* Goals, requirements → iterative design → bring to readiness • *Invest:* R&D, necessary technologies → bring to readiness • *Estimate:* effort, cost, schedule, reserves, risks → refine to believability • *Govern:* progress oversight and decision-making

Comparison: Structural factors

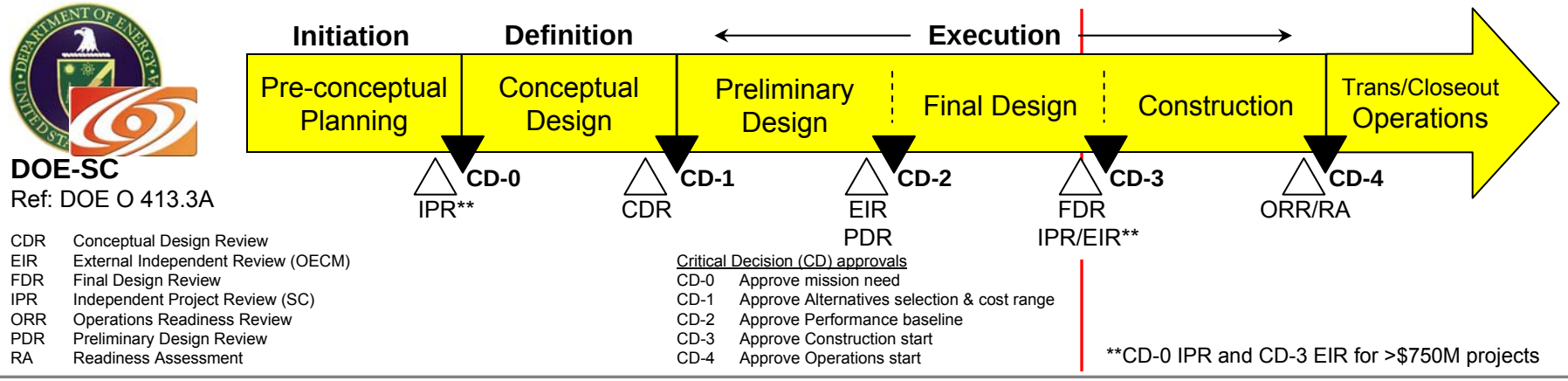


"Project assurance" structures

- **Provides policy**
- **Provides independent review**

FPD	Federal Project Director
OECM	Office of Engineering and Construction Mgmt
OPA	Office of Project Assessment
SRB	Standing Review Board
LFO	Large Facilities Office
NSB	National Science Board
S&E	Science and engineering

Development process crosswalk: Terminology and alignment



DOE-SC
Ref: DOE O 413.3A

CDR	Conceptual Design Review
EIR	External Independent Review (OECM)
FDR	Final Design Review
IPR	Independent Project Review (SC)
ORR	Operations Readiness Review
PDR	Preliminary Design Review
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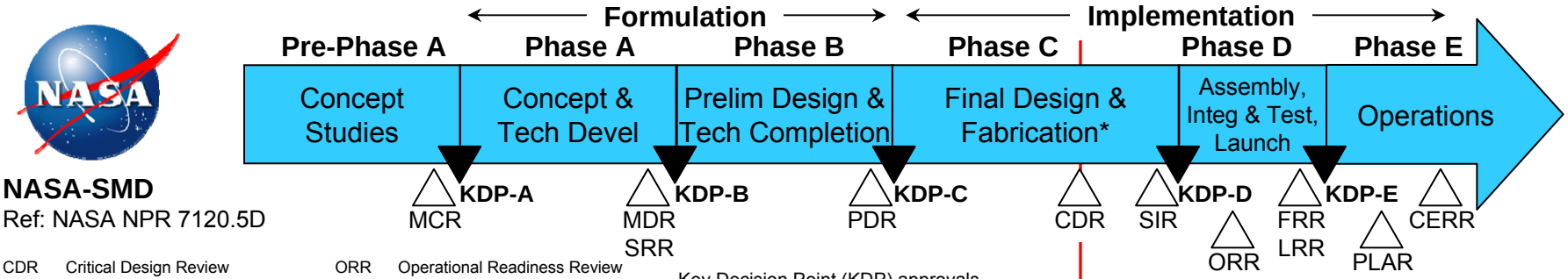
Critical Decision (CD) approvals

CD-0	Approve mission need
CD-1	Approve Alternatives selection & cost range
CD-2	Approve Performance baseline
CD-3	Approve Construction start
CD-4	Approve Operations start

**CD-0 IPR and CD-3 EIR for >$750M projects



NASA-SMD
Ref: NASA NPR 7120.5D

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Key Decision Point (KDP) approvals
KDP-C Approve Implementation

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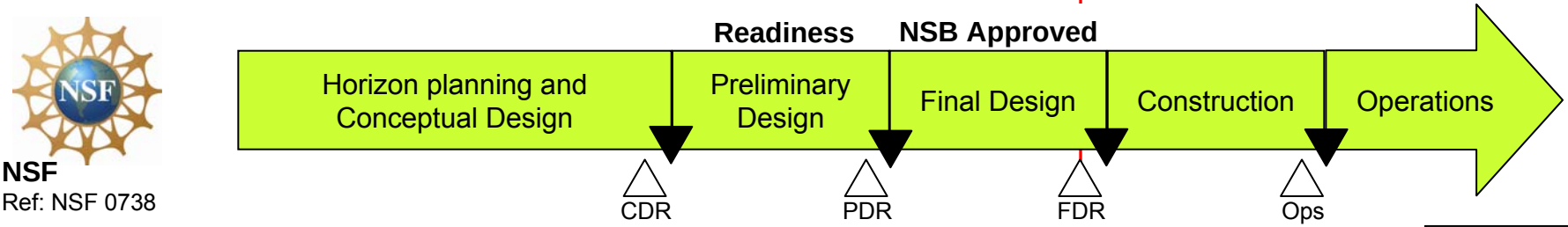

NSF
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Approvals

Post-CDR	Approve advance to Readiness
Post-PDR	Approve submission to Nat. Science Board (NSB)
Post-FDR	Congress appropriates MREFC funds
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△ Review ▼ Decision

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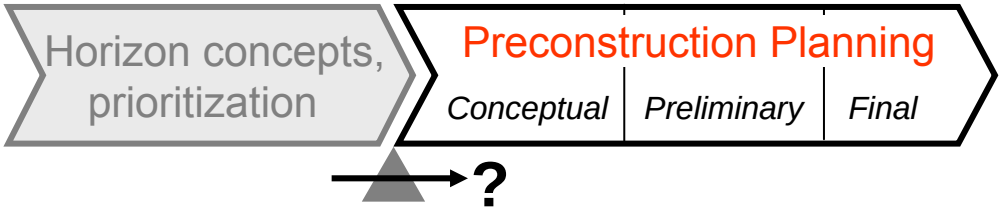
Comparison: On-Ramps *(when does a project start?)*



"Mission-driven" – projects determined via strategically-defined goals and priorities

DOE

- Projects identified in the SC 20-year prioritized facility plan[1]
- Establish "mission need", feasibility at CD-0 → Definition phase

NASA

- Strategic and Science Plans[2] based on Decadal Surveys, roadmaps.

Two flavors:

- *Strategic missions* are internally initiated (KDP-A) and managed
- *"PI-led" missions* are competed in Phase A → selected → Phase B

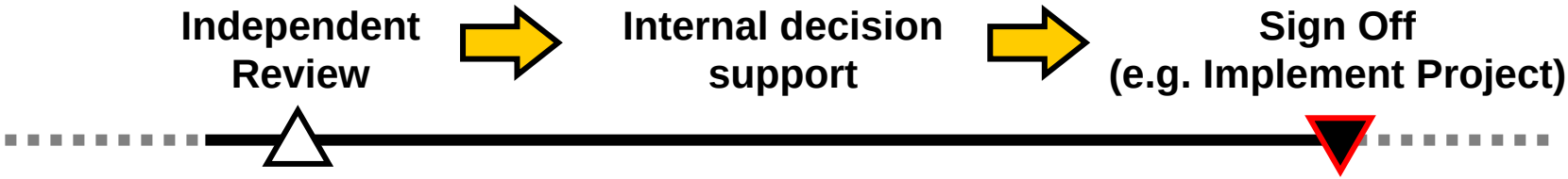
"Community-driven" – projects "bubble up" from the scientific disciplines

NSF

- Peer-reviewed unsolicited proposals, workshops, studies, etc.
- Evolved concepts *may* be brought to development

1. Facilities for the Future of Science, A twenty year outlook, DOE/SC-0078, Dec 2003; and Four Years Later: an Interim Report on Facilities for the Future…, Aug 2007. 2. NASA Strategic Plan, 2006; and NASA Science Plan 2007–2016

Comparison: Governance and oversight



	Independent Review	Internal decision support	Sign Off (e.g. Implement Project)
DOE	**PDR** by OPA "Lehman Review" (also: EIR by OECM)	Energy Systems Acquisition Advisory Board (ESAAB) • OPA briefs AE, calls ESAAB • Federal Project Director	**CD-2** **Acquisition Exec (AE)** (DepSec, US Sci, SC Dir/AD) Approve Performance Baseline (Enter Final Design Stage)
NASA	**PDR** by Standing Review Board	Program Mgmt Council • Program Manager • Center Mgmt Council • Technical Authority • Project Manager	**KDP-C** **Decision Authority (DA)** (AA for Cat 1, otherwise MDAA) Approve Implementation (Enter Phase C – Final Design & Fab)
NSF	**PDR** by Review Panel	NSF Director MREFC* Panel • CFO, DDLFP • Directorate/Division • **Program Officer**	**NSB Approval** for inclusion in a future budget in MREFC* construction account

* Major Research Equipment and Facilities Construction

Comparison: Independent reviews

DOE Expert Panels

- Run by SC Office of Program Assessment (OPA)
- Chair always a DOE federal employee (usually from OPA)
- Evolving membership of DOE staff, contractors, other experts; usually a core group, but introduce “new blood” as project evolves

NASA Standing Review Board (SRB)

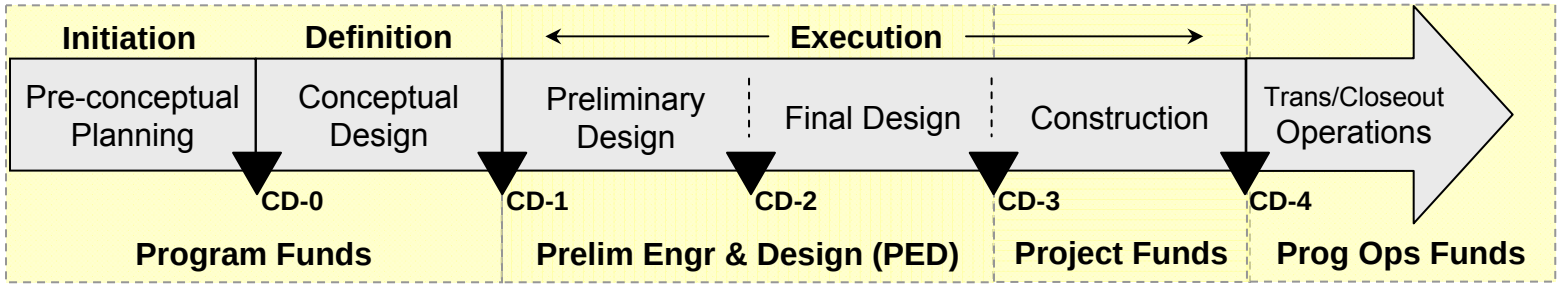
- Coordination: Independent Program Assessment & Oversight Office (IPAO)
- Chair vetted and agreed by project, program, Decision Authority
- Fixed membership of NASA staff, contractors, other experts (selected by chair) follows entire lifecycle, including subsystem reviews. Add experts as needed.

NSF Expert Panels

- Assembled for each review by Program Officer with assistance of DDLFP, and possible input by invited chair.
- Changing membership of external technical and scientific experts, but often try to keep a core group for institutional memory.

Comparison: Funding

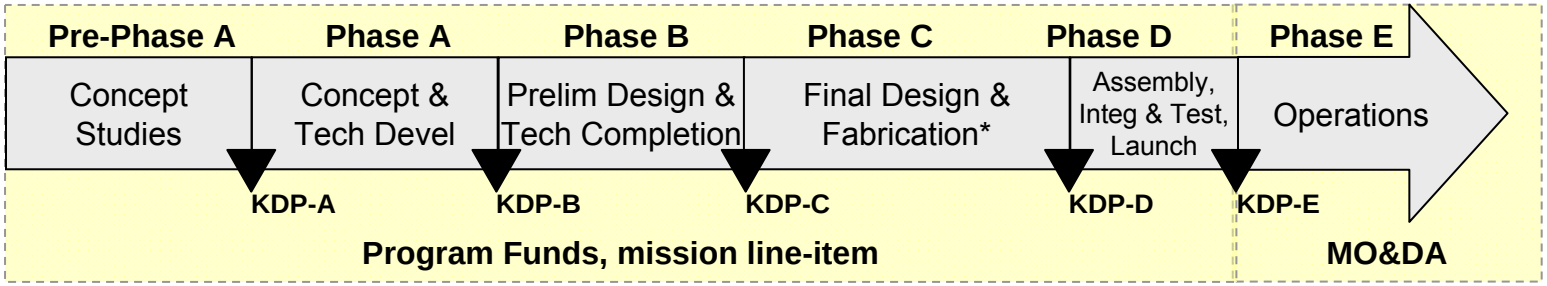
DOE-SC



• *Separate funds support research*

Type: Line Item (LI), O&E, MIE (Major items & equipment ~ no construction)

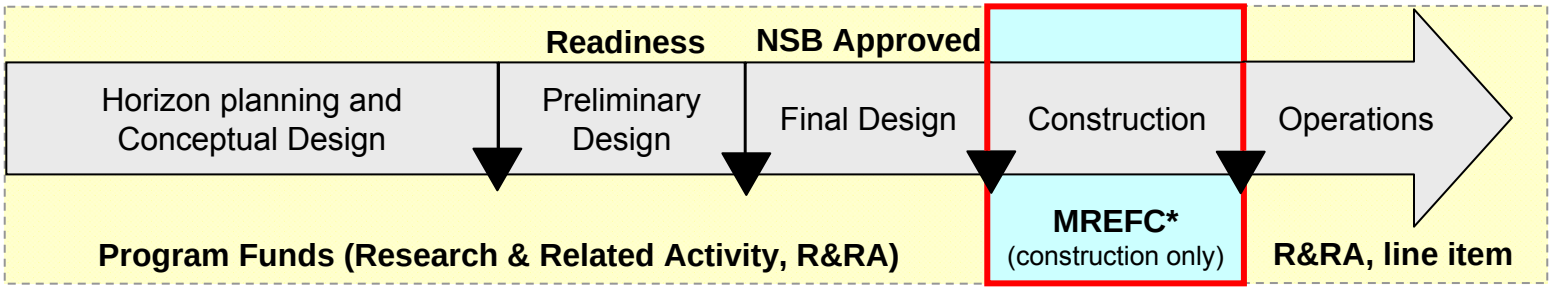
NASA-SMD



• *Separate Research and Analysis (R&A) funds support research*

Mission Operations and Data Analysis

NSF



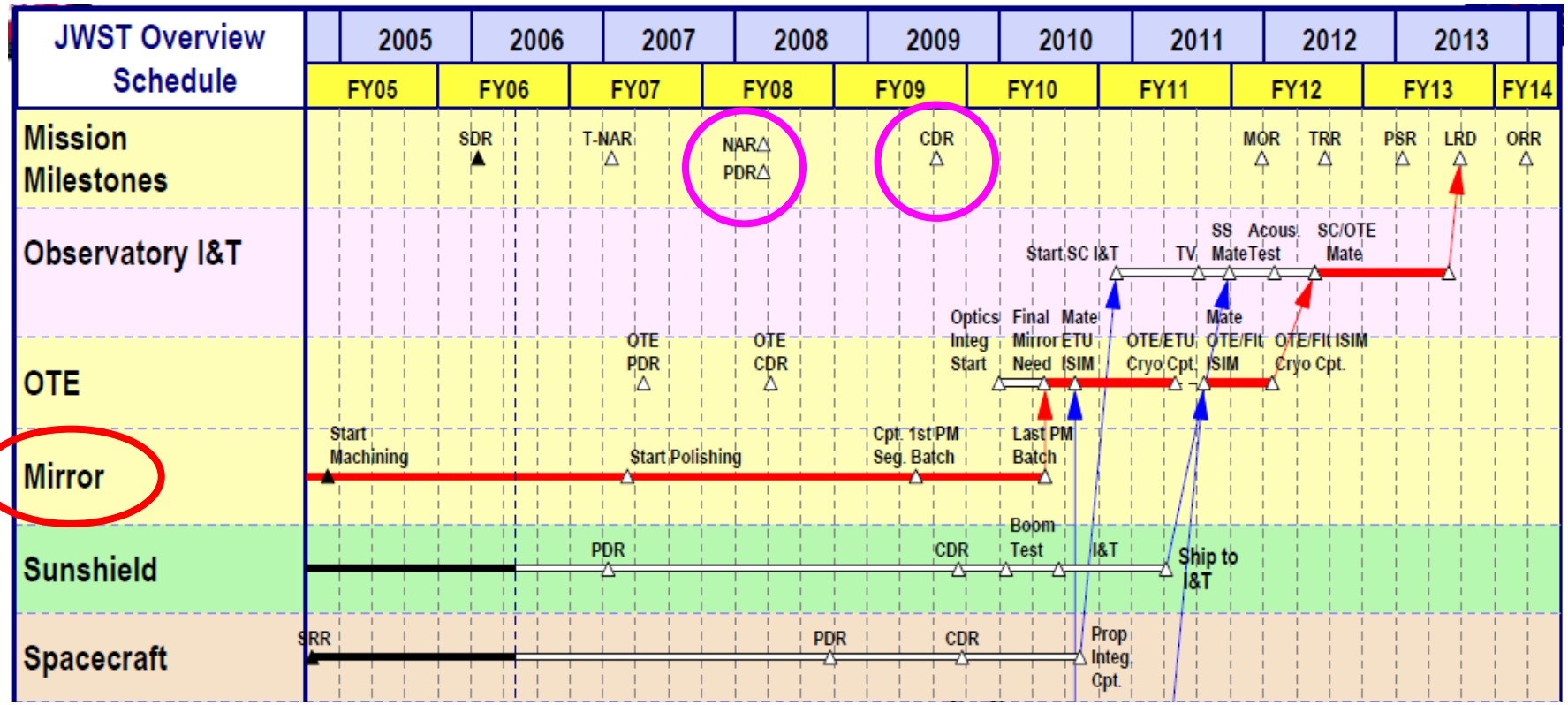
• *<u>Same</u> R&RA funds support research*

Requires separate Appropriation made earlier

* Major Research Equipment and Facilities Construction

Comparison: Acquisition start

- NSF: No construction-related acquisition until MREFC funds are appropriated, and awarded.
- DOE and NASA can acquire “long-lead items” after project initiation (CD-1, KDP-B), per approved project plans.



Comparison: Operations planning

DOE

- Not called out in O 413.3A.
- However, cost estimation during preconstruction planning is based on the lifecycle including operations – employed for alternatives analysis (for CD-1 milestone).

NASA

- Detailed operations planning is integral to (and a key driver for) the design effort.
- Life Cycle Cost Estimation includes ground and flight operations.

NSF

- Operations plans and cost estimation are required during preconstruction planning.
- NSF projects often have early operations ramp-ups.
- Cases of applying cost caps to operations phases.
- Approvals consider impacts to R&RA portfolios.

- *Funds for user support (pre- and post-project) varies*

Comparison: Performance

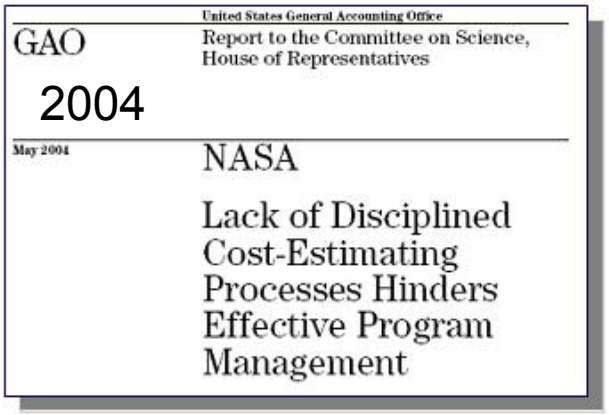
- **DOE/SC** ~ GAO May 2008 report
  - 89% completed on cost, 78% on schedule (70% for both; N=27).
  - Both small and large projects were successful.
  - "Shrinking pool" of qualified management and technical personnel cited as a main challenge (also see DOE 2008 Root Cause Analysis).

- **NASA/SMD** ~ GAO March 2009 on large projects
  - 10 of 13 projects had significant cost and/or schedule growth (average of 13% cost increase relative to baseline estimate, average 11-month launch delay, after 2-3 years in implementation (N=13)
  - Causes: technologies (new and heritage retrofits), managing contractors, inadequate assessment of risks and challenges.
  - ❖ *(From interviews: lingering effects of "Faster, Better, Cheaper")*

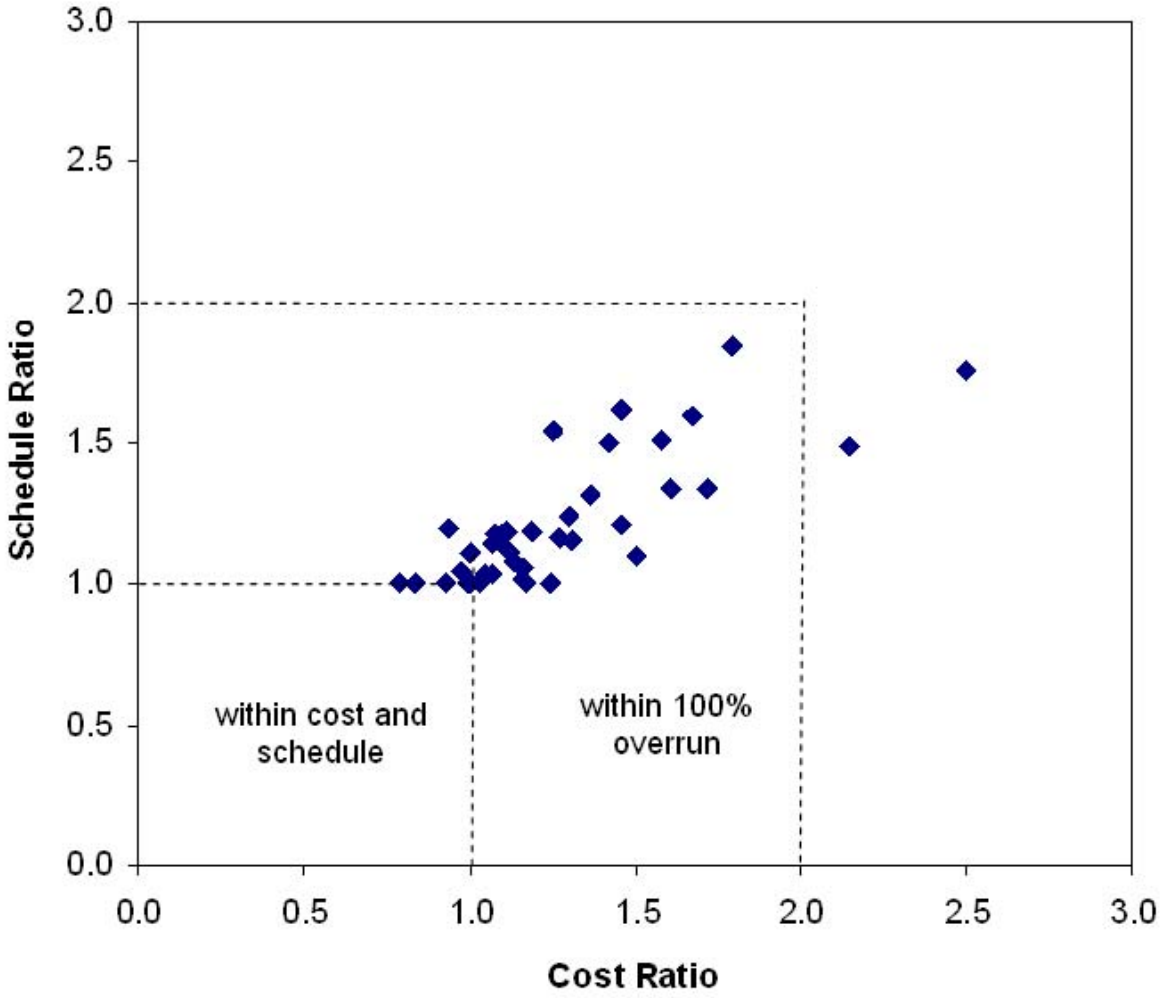
- **NSF** ~ no similar external analysis of project outcomes.
  - FY 2008 NSF Performance Report: ≥73% of MREFC projects since 2004 met self-imposed performance goal of <10% cost and schedule EVM variances.

Forty NASA Robotic Science Missions Experienced 27% Cost and 22% Schedule Growth

1992



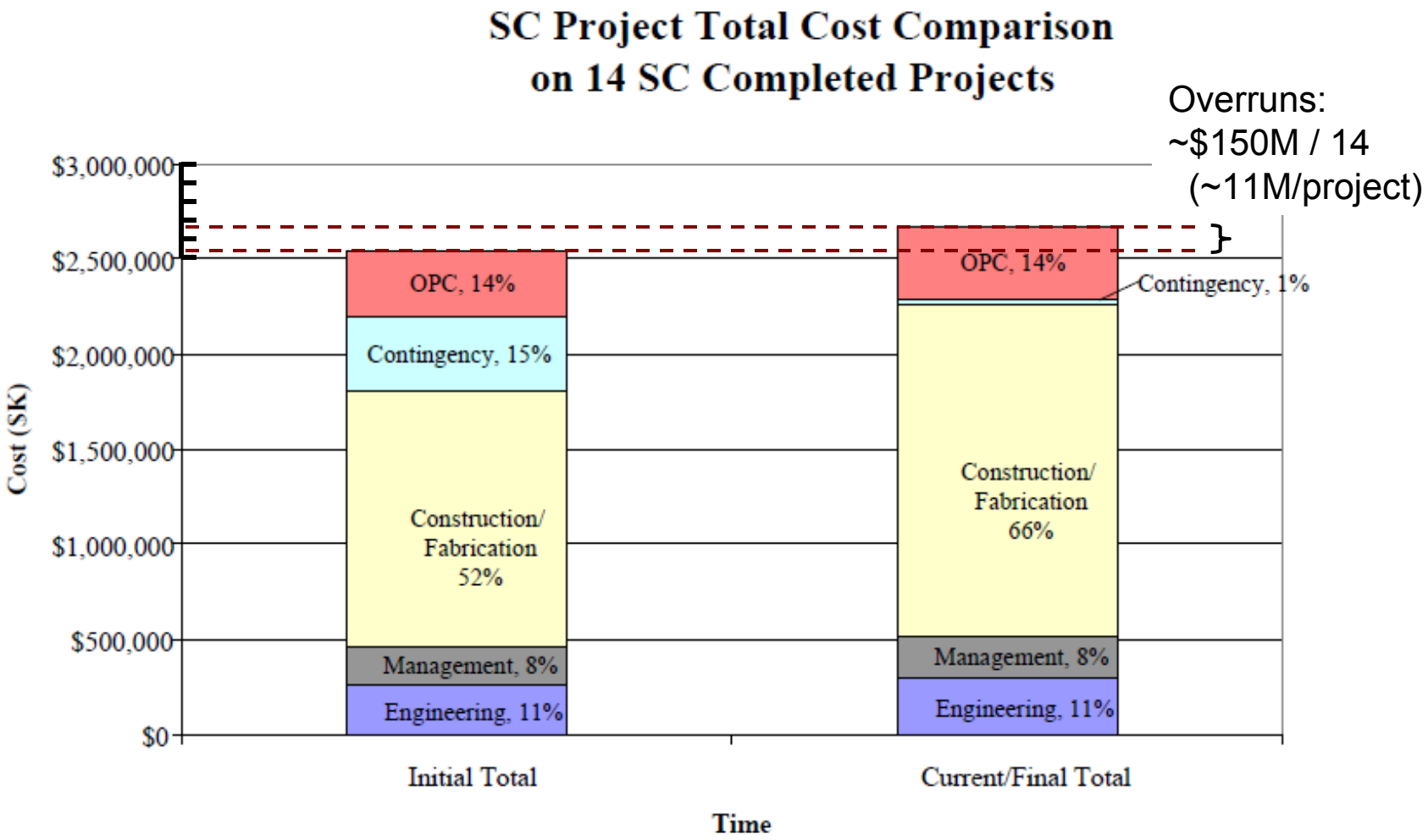
2004



-- David Bearden, June 3, 2008

THE AEROSPACE CORPORATION

DOE SC/OPA Cost survey – Mar 2009

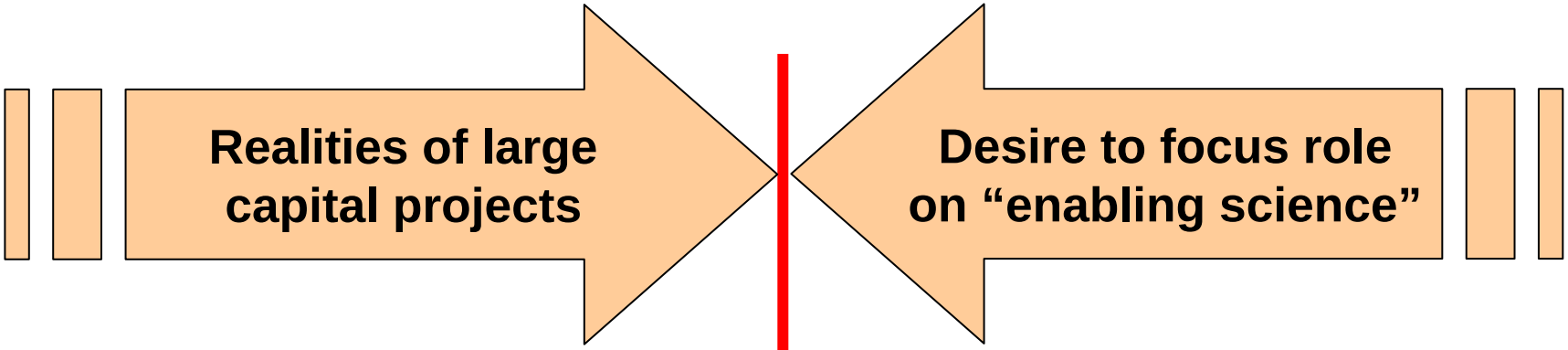


http://www.er.doe.gov/opa/PDF/Overview%20Cost%20Pres%20Web%20Vs.pdf

Today's talk

- Scope definition
- Agency comparisons
  - Structural factors
  - Processes
  - Governance & oversight
  - Funding, cost estimation, acquisition start
  - Performance
- **How can NSF improve its process?**
  - Perspectives and potential actions, from analysis and interviews
  - Partnering issues

Perspective on ownership from comparison & interviews



- Large, long-term investments
- Engage federal acquisition rules and performance standards
- High risk, visible and measurable

➢ *On congress & OMB radar screens: call **agency** not awardee with taxpayer cost concerns!*

- Respond to needs defined by the scientific communities
- Community will operate facility
- NSF helps organize and rationalize

➢ *Stay as close as possible to the research funding model (and 5% overhead tradition)*

small — **Organizational investment** — large

In internal facility management capability

(based on perceived level of ownership)

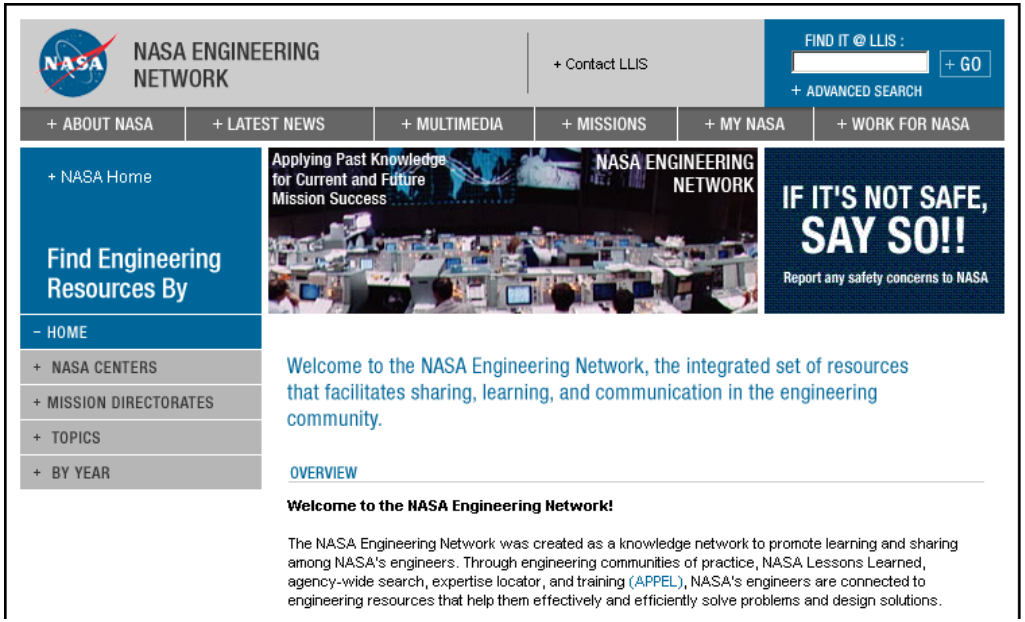
Potential actions to improve NSF management of large facilities

Portfolio analysis	• Currently within directorates (as at other agencies), e.g. MPS, GEO efforts). • **Institute Foundation-wide portfolio tracking** for overall performance and risk assessment (e.g. DOE/SC OPA EDIA efforts).
Staffing	• **Add more permanent staff** with project management experience: might be "matrixed" resources across Foundation (a trend within directorates?) • "No operation of laboratories" doesn't seem to prevent having more planning and oversight staff, but would impact NSF's traditional 5% overhead level
Process	• **Earlier initial prioritization** (currently late in investment path and relative to other agencies). Impacts cost tracking and partner synchronization. • **Clarify "project start"** (first event in Large Facilities Manual is CDR). • NSF leads novel class of distributed systems of systems (Earthscope, OOI, NEON), but performance (and utilization) are NSF-level exposure risks. • Consider more NASA-like emphasis on **formal Integration and Test planning** and **utilization planning**, for these facilities. • **Expand MREFC-defined best practices** to all major multi-user facilities.
Lessons learned	• Could require delivery and publication of **project close-out reports** with detailed histories and lessons learned similar to DOE and NASA practices.

Lessons Learned

NASA

- Required for all development activities (NPR 7120.6)
- "Preserve institutional knowledge, correct deficiencies and improve performance"
- **public searchable website**
  http://ildp1.nasa.gov/offices/oce/llis/home/



DOE

- On-line LL repositories for HQ and Labs, and guidance documents
- Project Closeout reports provide detailed histories

NSF

- Lessons Learned activities by facility awardees and collaboratively (e.g. NSTC Physics of the Universe WG)

Partnering issues: "Impedance (mis)matches"

Lessons learned from GLAST

Capabilities & Practices

Strategic valuation

- Ensure that the scale of the contribution expected from DOE-HEP matches the importance of the science to our core mission
- Listen carefully to our advisory committees and follow up on their recommendations

Technical domains

- Understand the cost impact of building detectors which
  - Can tolerate speed of 10*g* and temperature variation of >150°
  - Will have 100% reliability under extreme conditions

Management practices

- Clearly define responsibilities for interagency ventures
  - Especially when project rules, performance measures, and culture are very different
- Upfront planning manpower resources

➢ ***Could envisage a matrix of COMPLEMENTARITY across capabilities, practices, lessons learned, etc…)***

-Source: R. Staffin, 14Feb2006, FY06 presentation to HEPAP, *www.er.**doe**.gov/hep/files/pdfs/HEPAPFeb142005Staffin.pdf*

Conclusions: Implications for partnering

- **Agency processes** are aligned fairly well at the top-level; and many similarities in practices and management/assurance structures.

  → Bodes well (in theory) for interagency collaborations.

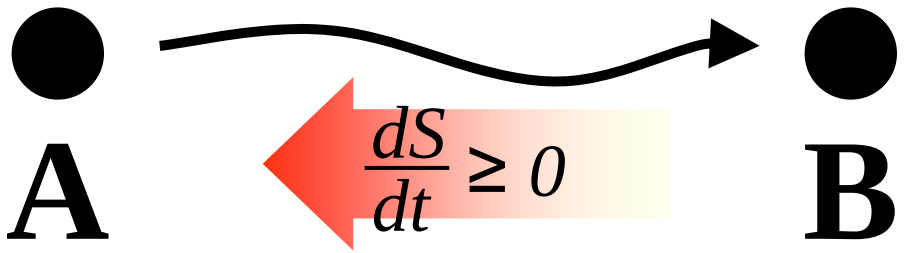
- Differences in structure, funding (e.g. MREFC), technical capabilities, would tend to be magnified on bigger, complex projects.

  → Suggests starting collaboration efforts as early as feasible. And create an integrated development and decision process (i.e. more than a Joint Oversight Group).

- **Knowledge-dissemination**
  - Increasing collaboration has not yet translated into wide understanding of partner processes and practices.
  - Internal diffusion and acceptance of new processes and best practices is ongoing at NSF and NASA.
  - Scarcity of project managers and technical staff is a common issue.

  → Create a *cross-agency training program* for collaboration-ready managers, via the "Project Assurance" offices (SC/OPA, NSF/LFO, NASA/OCE)?

Summary and reference material

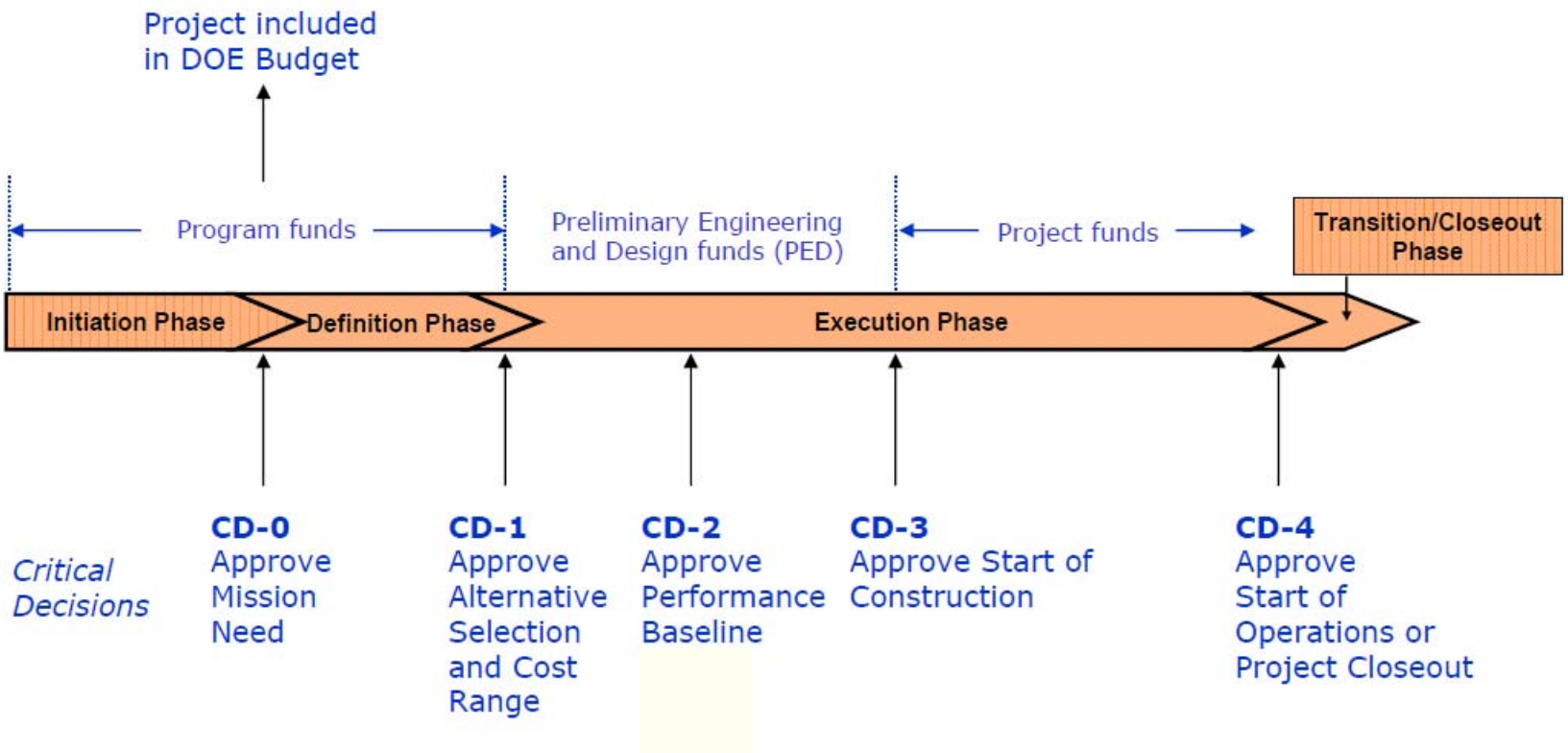


Development Policies & Procedures are captured formally

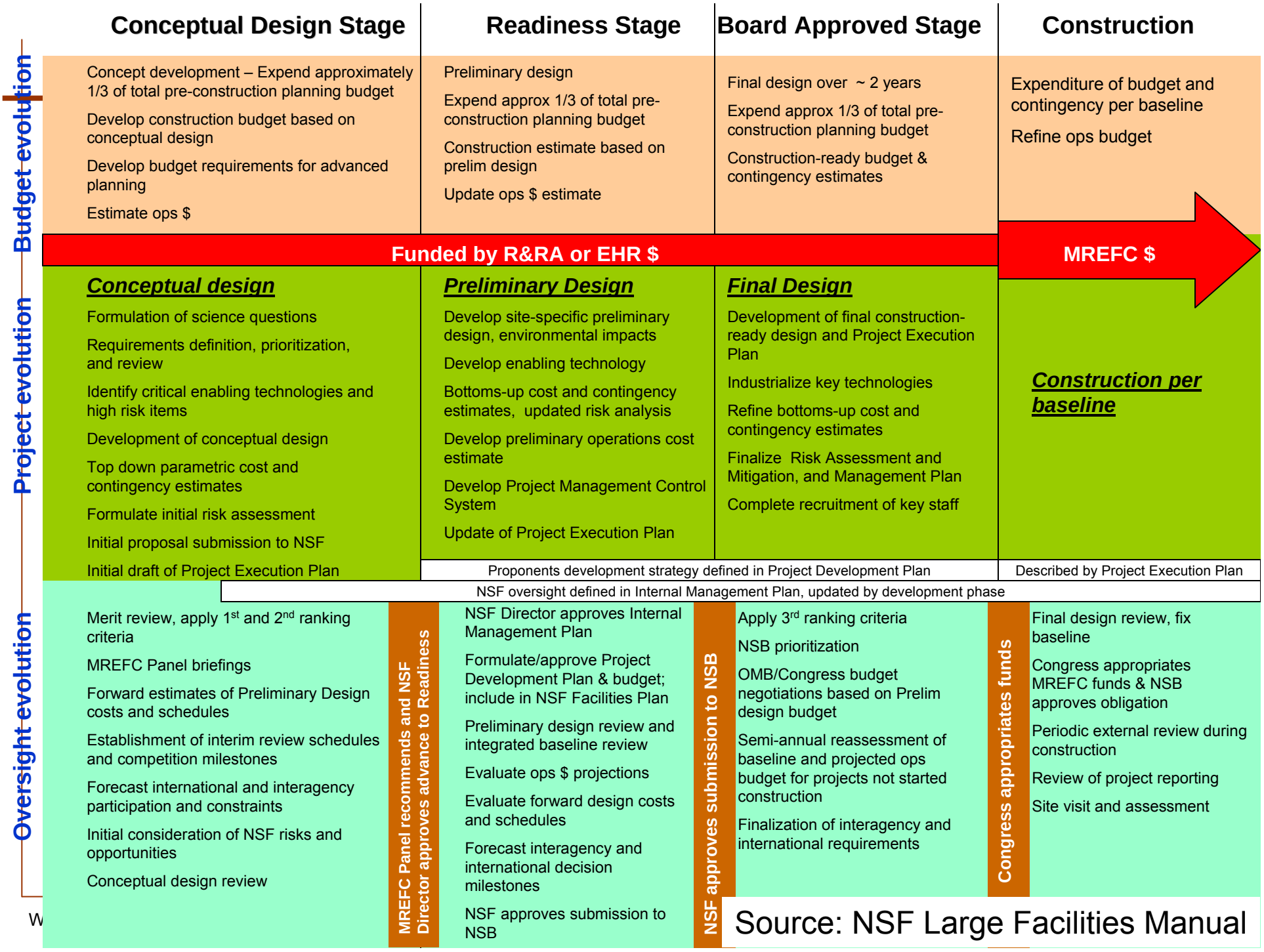
	Title	ID	Originator	Released
DOE	"Program and Project Management for the Acquisition Of Capital Assets"	Order 413.3A	Office of Engineering and Construction Management (OECM)	July 2006
NASA	"Space Flight Program & Project Management Requirements"	NPR 7120.5D	Office of the Chief Engineer	Mar 2007
NSF	"Large Facilities Manual"	NSF 0738	Large Facilities Office (in the Office of Budget, Finance & Award Mgmt)	May 2007

- *Documents represent top-level "Best Practices" for science platform development at each agency, by project policy/assurance offices*
- *Processes interpreted and implemented by the program directorates*
- *Current editions are all quite recent (and still evolving)*

DOE Lifecycle Process – from O413.3A

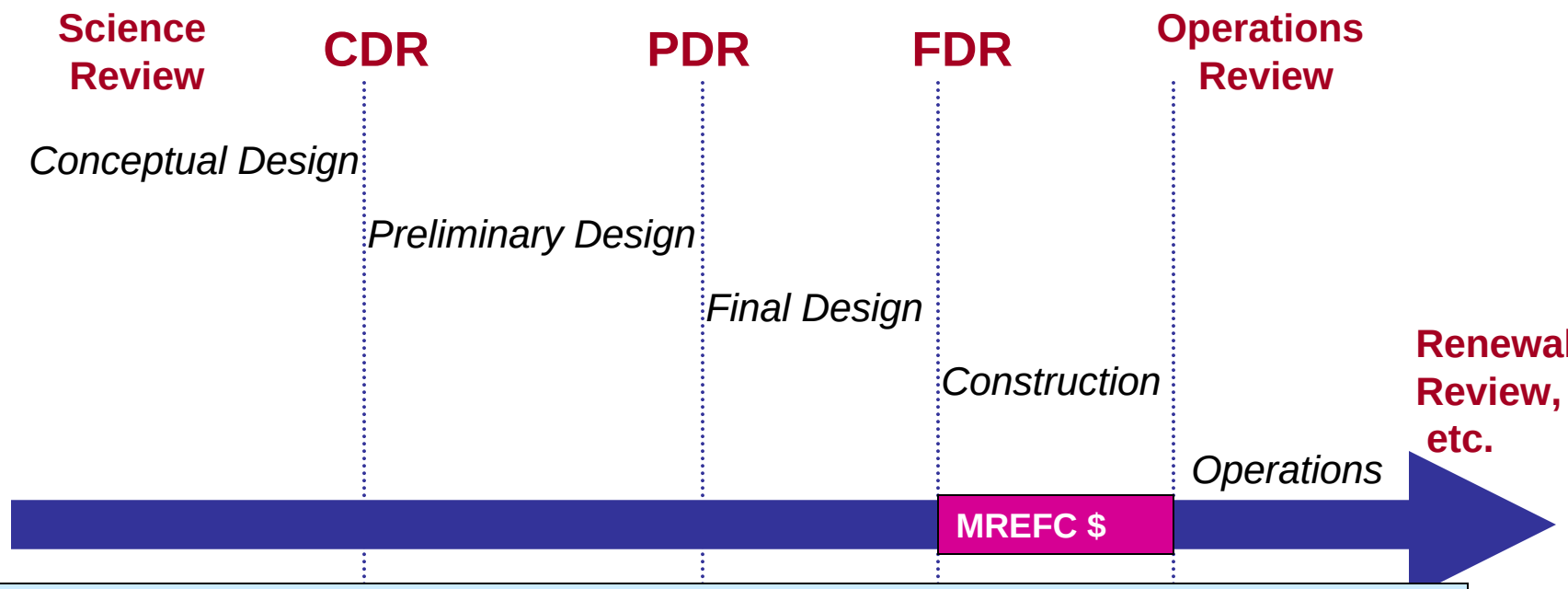


Source: S. Meador, Feb 2009, based on DOE Order 413.3A



Source: NSF Large Facilities Manual

NSF vs. Doe Process

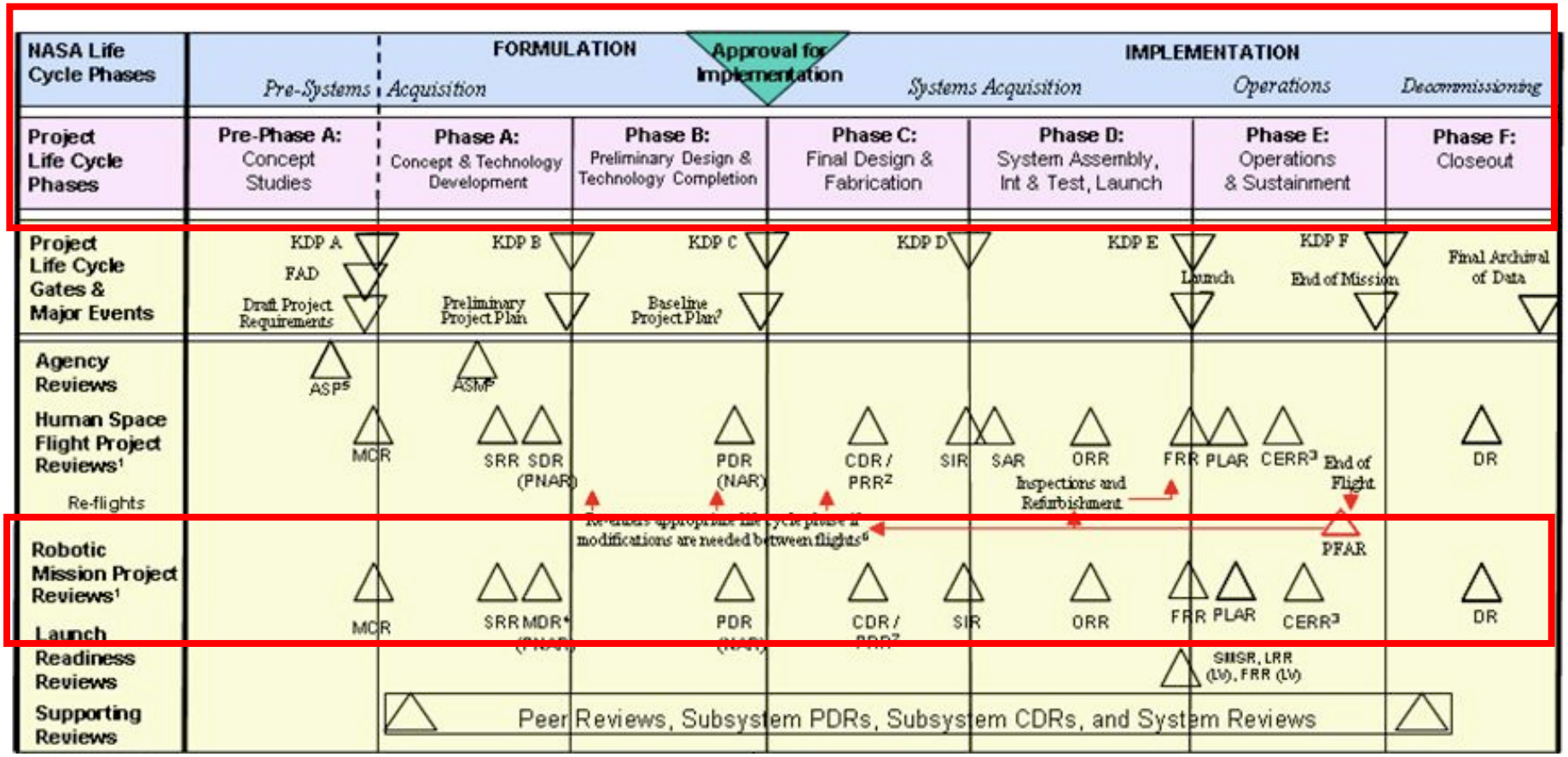


Approximate DOE Translation:

CD 0	***CD 1***	***CD 2***	***CD 3***	***CD 4***
Approve mission need	Approve alternate selection and cost range	Approve performance baseline	Approve construction start	Approve operations start

-- Source: M. Coles

NASA Project Life Cycle Process – from NPR 7120.5D



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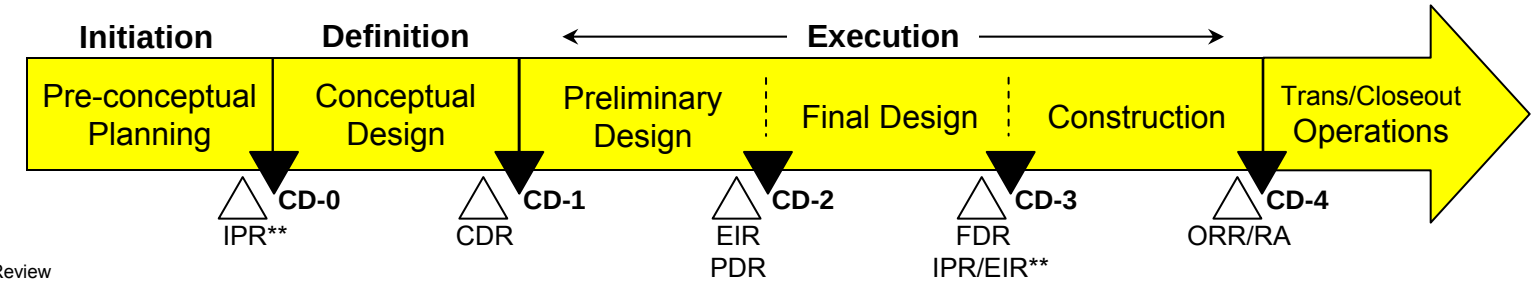

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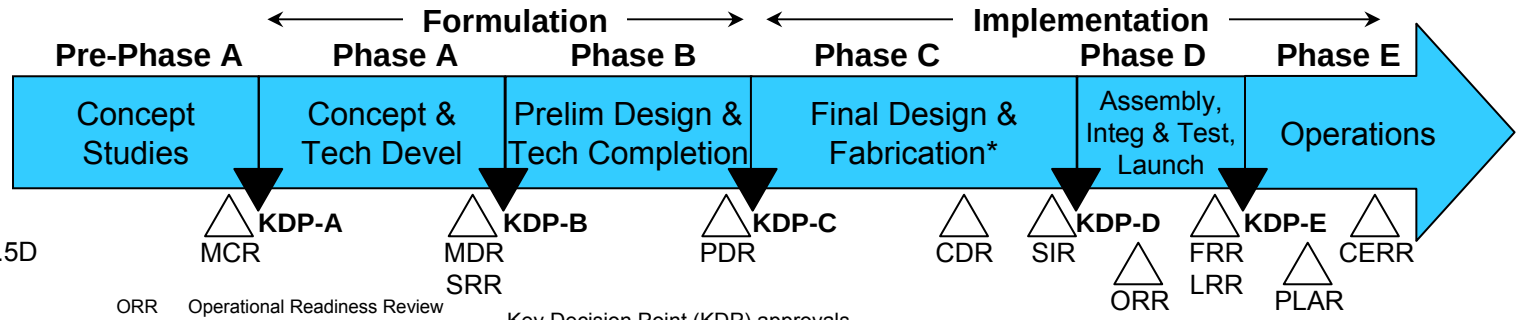

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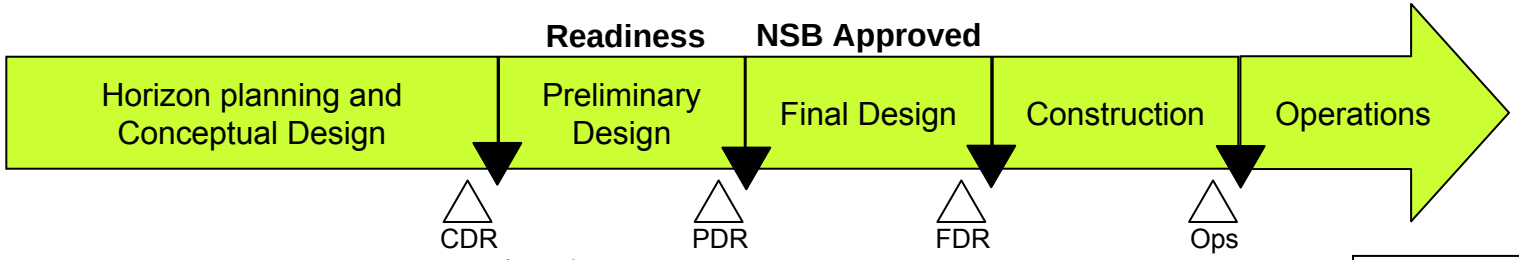

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△ Review ▼ Decision

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Summary of agency structural differences

Science vs. other agency missions

- **DOE and NASA** science organizations embedded among other major missions.
- **NSF** singly focused on enabling science, via peer-review and outflow of research awards.

Internal Resources

- **DOE and NASA** have in-house project and technical resources (Labs and Centers).
- **NSF** governed by 42 U.S.C.§1873b ("shall not operate laboratories").

Project-related factors

- **DOE** has extensive legacy infrastructure: can leverage this for new projects, but labs cost a lot to maintain and *need* new projects to rejuvenate.
- **NASA** spaceflight projects have high risk of catastrophic failure and operate remotely in harsh environments ~ Drives extremes of planning, system test, oversight, etc.
- **NSF** large facilities are highly varied – e.g. giant telescopes to distributed sensor networks – and in new disciplines unfamiliar with large facilities (e.g. EarthScope, OOI, NEON).

Project cost categorization determines governance

DOE Cost categories : 5-20, 20-100, 100-400, 400-750, >750 ($M)

- Approval level depends on cost category
- Highest category requires DOE Deputy Secretary approval

NASA Cost Categories: based on Life Cycle Cost Estimate (LCCE):

(1) > $1B (or nuclear powered or human spaceflight)
(2) $250M to $1B
(3) < $250M (High Priority projects at this cost may be Cat 2)

- Approval level depends on project category
- Highest category requires NASA Administrator approval

NSF Either MREFC (eligibility based on 10% rule) or non-MREFC

- MREFC Approvals by NSF Director and National Science Board
- Non-MREFC projects governed internally within Directorates

Independent cost estimation

DOE

- Lifecycle cost estimate important for Alternatives Analysis at CD-1
- “Bottoms-up" ICE or Independent Cost Review as part of External Independent Review for CD-2

NASA

- Project-derived: Life-Cycle Cost Estimate (LCCE).
- ICE prepared and owned by the Standing Review Board (SRB), generally developed using primarily parametric estimating methods, also supplemented via factors and methods. Based on same definitions and technical baseline as LCCE

NSF

- Bottoms up Cost estimate in proposal.
- NSF may engage a contractor to produce a parametric/top-down cost estimate for comparison.

Acronyms

CD	Critical Decision (DOE)
CDR	Conceptual Design Review (DOE, NSF) Critical Design Review (NASA)
DDLFP	Deputy Director for Large Facility Projects, head of LFO (NSF)
EIR	External Independent Review (DOE OECM)
IPAO	Independent Program Assessment & Oversight Office (NASA)
KDP	Key Decision Point (NASA)
LFO	Large Facilities Office (NSF)
MO&DA	Mission Operations and Data Analysis funding account (NASA)
MREFC	Major Research Equipment and Facilities Construction funding account (NSF)
NAR	Non-Advocate Review (PDR, NASA)
OECM	Office of Engineering and Construction Management (DOE)
OPA	Office of Program Assessment (DOE/SC)
PED	Preliminary Engineering and Design funding account (DOE)
PDR	Preliminary Design Review
PNAR	Preliminary Non-Advocate Review (MDR, NASA)
R&RA	Research and Related Activities funding account (NSF)
R&A	Research and Analysis funding account (NASA)
SC	Office of Science (DOE)
SRB	Standing Review Board (NASA)
SMD	Science Missions Directorate (NASA)