National Science Foundation

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2nd Cosmic Explorer Symposium

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How does NSF support large projects?

- NSF supports large projects (above $100M) through the Major Research Equipment and Facilities Construction (MREFC) account.
- Initial planning and design and post-construction operation and maintenance are supported through the Research & Related Activities (R&RA) account.

NSF Budget Request FY2025

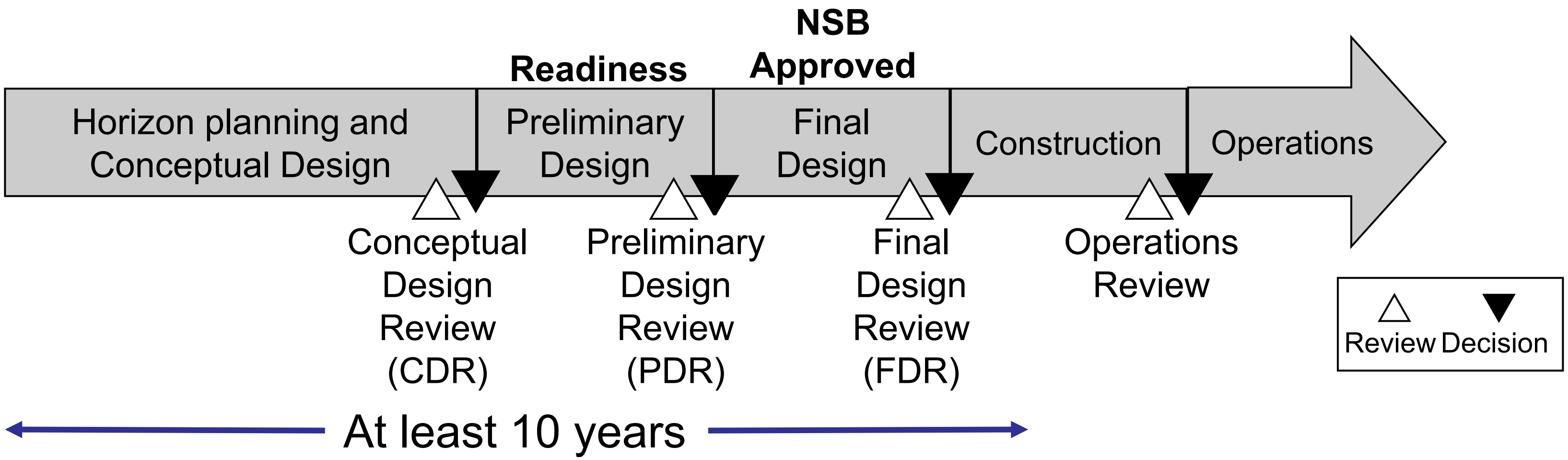
MREFC Account Funding, by Project

(Dollars in Millions)

	FY 2023 Base Plan	FY 2024 Request	FY 2025 Request	FY 2026 Estimate	FY 2027 Estimate	FY 2028 Estimate	FY 2029 Estimate	FY 2030 Estimate
Antarctic Infrastructure Recapitalization (AIR)	$60.00	$60.00	$60.00	$60.00	$60.00	$60.00	$60.00	$60.00
HL-Large Hadron Collider Upgrade	33.00	38.00	-	-	-	-	-	-
Leadership-Class Computing Facility (LCCF)	-	93.00	154.00	226.00	47.00	-	-	-
Mid-scale Research Infrastructure, Track 2[2]	76.25	105.06	85.00	90.00	100.00	100.00	100.00	100.00
Regional Class Research Vessel (RCRV)	1.98	-	-	-	-	-	-	-
Vera C. Rubin Observatory (Rubin)	15.00	7.61	-	-	-	-	-	-
Future Priority Projects[3]	-	-	-	8.00	206.00	264.00	289.00	339.00
Dedicated Construction Oversight	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Total	**$187.23**	**$304.67**	**$300.00**	**$385.00**	**$414.00**	**$425.00**	**$450.00**	**$500.00**

3 Represents escalating funding amounts increasing NSF's MREFC portfolio to a total of $500.0 million by the end of the decade and does not reflect policy decisions on project-specific investments. Increases reflect both anticipated growth in cost of major research infrastructure, as well as NSF's intent to increase investments in facilities to maintain U.S. leadership in key science and engineering research areas.

NSF's large facility project planning process?



- **Review science goals**
- **Conceptual Design Stage**
  - Requirements, initial estimates of cost (including operations), risk and schedule
- **Preliminary Design ("Readiness") Stage**
  - Definition and design of major elements, detailed estimates of cost, risk and schedule, partnerships, siting
- **Final Design Stage ("Board Approved") Stage**
  - Interconnections and fit-ups of functional elements, refined cost estimates based substantially on vendor quotes, construction team substantially in place

Conceptual Design (CD)

- Science goals defined
- **SCOPE:** Functional requirements/operating capabilities flow from science requirements
- **BUDGET:** Parametrically derived, risk-adjusted, top-down, site-independent. WBS framework employed to define project elements.
- **SCHEDULE:** Will be viewed skeptically, but do your best
- Rough order of magnitude operating cost projections – also viewed skeptically
- **MANAGEMENT:** Skeletal framework for Project Execution Plan
- **Work plan for getting to Preliminary Design:** Issue spotting - Environmental or other regulatory issues defined, including work that must be done by NSF if lead agency.

Preliminary Design (PD)

- **SCOPE:** Functional requirements flow down to define a site-dependent design, interconnections between functional components, credible industrial implementation plan.
- **BUDGET:** Bottom-up estimate, WBS with dictionary, basis of estimate, algorithmic determination of risk $, cost/schedule impacts of regulatory issues understood.
- **SCHEDULE:** Resource loaded schedule, critical path defined; work is technically placed and determines budget profile.
- **MANAGEMENT:** Key staff can credibly lead the project.
- **OPERATING COSTS:** Projected operating costs are supported by credible analysis.

PD defines work scope and budget that can, with high confidence, deliver the project.

THIS IS THE BASIS FOR CONSTRUCTION FUNDING REQUEST TO CONGRESS

Final Design (FD)

- **SCOPE:** Detailed design that forms the basis for bid packages.
- **BUDGET:** Significant proportion of costs based on external data: vendor estimates, quotes; plans for subawardee oversight, project management.
- **SCHEDULE**: Schedule includes vendor information.
- **MANAGEMENT:** Credible project team, MOUs clearly define partner roles and responsibilities, realistic acquisition plan.

Project is "Shovel Ready"

THIS IS THE BASIS FOR NSB OBLIGATION OF FUNDS TO AWARDEE TO COMMENCE CONSTRUCTION

Other NSF Expectations

- **NSF's "no overrun" policy**
  - Budget shortfalls must be made up by de-scoping.

- **Broader impacts**
  - Criteria for project selection
  - Leverage to exploit opportunity
  - *Capital costs to facilitate educational aspects can be included in construction budget*

- **Commissioning**
  - Can be part of construction budget, or operation
  - Commissioning activity must be distinguishable from operating activity if included in construction budget

What are the steps for Cosmic Explorer? (Dawn V 2019)

Horizon planning (3G Design NSF award in 2018)	3 years (2021)
Cosmic Explorer White Paper (3G Design award product)	
Community endorses the WP (through Dawn meeting?)	½ year (2021)
NRC report based on CE WP and GWIC reports	1 ½ years? (2023)
MPSAC subcommittee reviews NRC report	½ year (2024)
Physics Division develops a written plan for MPS approval	
NSF Director decides to authorize CD funding	
Conceptual Design period	2-3 years (2027)
Preliminary Design period award	2-3 years (2030)
NSF approves submission to NSB	½ year (2030)
Final Design period	2-3 years (2032)
NSB prioritization	
OMB/Congress budget negotiations	
Congress appropriates MREFC funding (2032-37)	**14 years (2032)**

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Future

- GW Detector construction will transition from a MREFC level (2G) to a supra-MREFC level (3G), similar to those of the largest scientific installations in the world (CERN, Fermilab, etc.)

- What worked for LIGO/Virgo in the past may be inadequate for projects like Einstein Telescope/Cosmic Explorer. More human resources need to be dedicated to the social/collaborative/organizational/political efforts

- The scientific and political paths ahead are not clear and they will possibly not be for a while
  - A management organization (awardee) must be identified
  - R&D and design concepts might need to be developed and re-developed
  - International collaborations must be formalized
  - Scientists and funding agencies need to work on a viable plan to support the construction and, also critically important, the operations of these installations

Auxiliary Slides

Lessons Learned from other MREFC projects

- Construction activity requires a big pre-construction investment (5-25% of total project cost - TPC)
- Project management is ~10% of TPC
- Costs to operate industrial strength project management software ~1-2% of TPC
- Uncertainty in Federal appropriation process and schedule are part of the landscape for Project Management and budgeting
- International partnerships have an intrinsic overhead cost that must be recognized, and different partners have different costs
- Defining the appropriate governance model
- Extraordinary projects are successful when led by extraordinary people. Detailed policies and agreements don't compensate for this.

Lessons Learned from other MREFC projects

- Big projects are inherently part of political dialogue because of the size of projected budgets
- Projects have foundered when political influence has resulted in premature project start with incomplete plans (RSVP, ITER, SSC, DUSEL) and there has been painful re-scoping with others (ALMA, SODV…)
- Cost growth between initial concepts and FDR costs have sometimes been 2-3 times initial estimates, or more (ALMA, ATST, NEON, OOI, ARRV…)

More about Budgets

- Projects in the \$500M → \$1B+ range:
  - Current Divisional budgets are \$250-400M each
  - Current Divisional operations budgets ~\$50M - \$100M+
  - NSF can provide partial support for very large new facilities as one of many funding sources
- **Projected operations costs are large perturbations on existing Divisional budgets**
- Easier to get construction funding than operations funding, generally also true for public/private partnerships
  - Explore other business models?
- Multi-agency partnerships are even riskier – more ways to say no!
  - (See: Assessment of Impediments to Interagency Collaboration on Space and Earth Science Missions, National Academies Press, 2011)

	Conceptual Design Stage	Readiness Stage	Board Approved Stage	Construction
Budget evolution	Develop construction budget based on conceptual design Develop budget requirements for advanced planning Estimate ops $	Expend ~5-25% of construction cost on planning and design activities during Preliminary and Final Design Construction estimate based on prelim design Update ops $ estimate	Final design over ~ 2 years Construction-ready budget & contingency estimates Update ops $ estimate	Expenditure of budget and contingency per baseline Refine ops budget
	Funded by R&RA or EHR $	Funded by R&RA or EHR $	Funded by R&RA or EHR $	MREFC $
Project evolution	***Conceptual design*** Formulation of science questions Requirements definition, prioritization, and review Identify critical enabling technologies and high risk items Development of conceptual design Top down parametric cost and contingency estimates Formulate initial risk assessment Initial proposal submission to NSF Initial draft of Project Execution Plan	***Preliminary Design*** Develop site-specific preliminary design, environmental impacts Develop enabling technology Bottoms-up cost and contingency estimates, updated risk analysis Develop preliminary operations cost estimate Develop Project Management Control System Update of Project Execution Plan	***Final Design*** Development of final construction-ready design and Project Execution Plan Industrialize key technologies Refine bottoms-up cost and contingency estimates Finalize Risk Assessment and Mitigation, and Management Plan Complete recruitment of key staff	***Construction per baseline***
		Proponents development strategy defined in Project Development Plan	Proponents development strategy defined in Project Development Plan	Described by Project Execution Plan
	NSF oversight defined in Internal Management Plan, updated by development phase			
Oversight evolution	Merit review, apply 1st and 2nd ranking criteria MREFC Panel briefings Forward estimates of Preliminary Design costs and schedules Establishment of interim review schedules and competition milestones Forecast international and interagency participation and constraints Initial consideration of NSF risks and opportunities Conceptual design review **MREFC Panel recommends and NSF Director approves advance to Readiness**	NSF Director approves Internal Management Plan Formulate/approve Project Development Plan & budget; include in NSF Facilities Plan Preliminary design review and integrated baseline review Evaluate ops $ projections Evaluate forward design costs and schedules Forecast interagency and international decision milestones NSF approves submission to NSB **NSF approves submission to NSB**	Apply 3rd ranking criteria NSB prioritization OMB/Congress budget negotiations based on Prelim design budget Semi-annual reassessment of baseline and projected ops budget for projects not started construction Finalization of interagency and international requirements **Congress appropriates funds**	Final design review, fix baseline Congress appropriates MREFC funds & NSB approves obligation Periodic external review during construction Review of project reporting Site visit and assessment