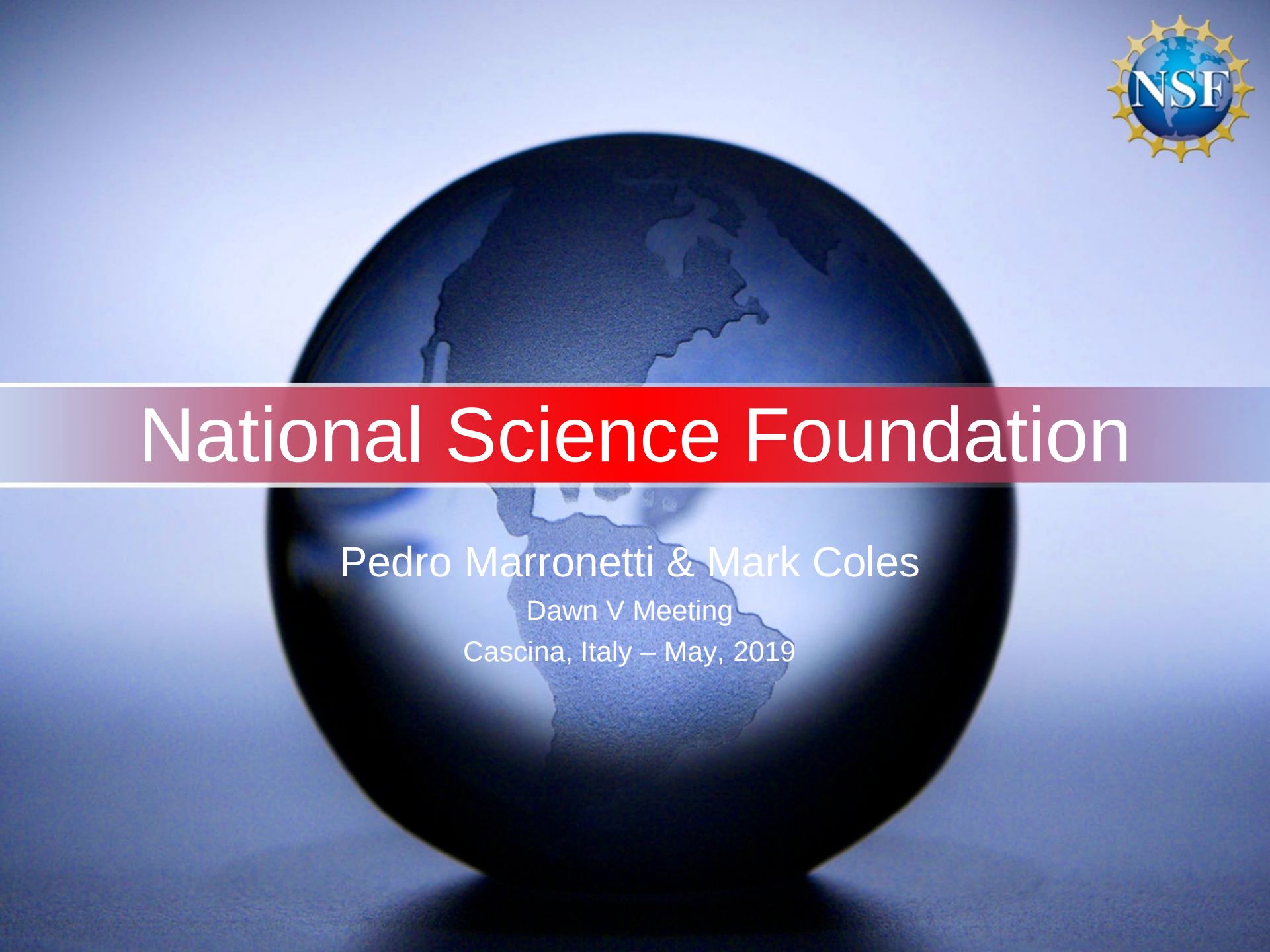


National Science Foundation

Pedro Marronetti & Mark Coles

Dawn V Meeting

Cascina, Italy – May, 2019

Gravitational Wave Agencies Correspondents (GWAC)

- The GW scientific community recommended *"… a closer link between the global funding agencies, to start to coordinate medium- and long-term planning, and looking for synergy between the agency capabilities to most effectively stimulate the field*." ("What Comes Next for LIGO?" Workshop, May 2015, Silver Spring MD.)

- NSF created an informal communication framework between funding agencies called "*Gravitational Wave Agencies Correspondents*" (GWAC).

- Homepage http://www.nsf.gov/mps/phy/gwac.jsp.

- The 4th meeting was be held on April 8. Members of GWIC gave a presentation on GWIC's 3G reports. GWAC will prove comments on the reports.

- Current member agencies: ARC (Australia), CFI (Canada), CNRS (France), CONACYT (Mexico), DFG (Germany), DAE (India), ESA (Europe), FWO (Belgium), INFN (Italy), NASA (US), NSF (US), NWO (Netherlands), STFC (UK).

How does NSF support large projects?

- NSF support large projects (above $70M) 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.

MREFC Account Funding, by Project

(Dollars in Millions)

	FY 2016 Actual	FY 2017 Estimate	FY 2018 Request	FY 2019 Estimate	FY 2020 Estimate	FY 2021 Estimate	FY 2022 Estimate	FY 2023 Estimate
DKIST	$20.00	$20.00	$20.00	$16.13	-	-	-	-
LSST[1]	92.97	67.12	57.80	48.82	46.34	40.75	5.36	-
NEON[2]	128.51	-	-	-	-	-	-	-
NEON transfers[3]	*[20.00]*	*[15.58]*	-	-		-	-	-
RCRV[4]	-	106.00	105.00	44.50	-	-	-	-
Enhanced Oversight	0.02	-	-	1.00	1.00	1.00	1.00	1.00
Total	**$241.50**	**$193.12**	**$182.80**	**$110.45**	**$47.34**	**$41.75**	**$6.36**	**$1.00**

MREFC examples and Stats

Initial LIGO

NSF Total: $272M*

Operations: $33M/year**

Advanced LIGO

NSF Total: $205M

Operations: $45M/year

ALMA

NSF Total: ~$500M

International Total: ~$800M

Operations: $121M/year (NSF covers 37.5%)

LSST

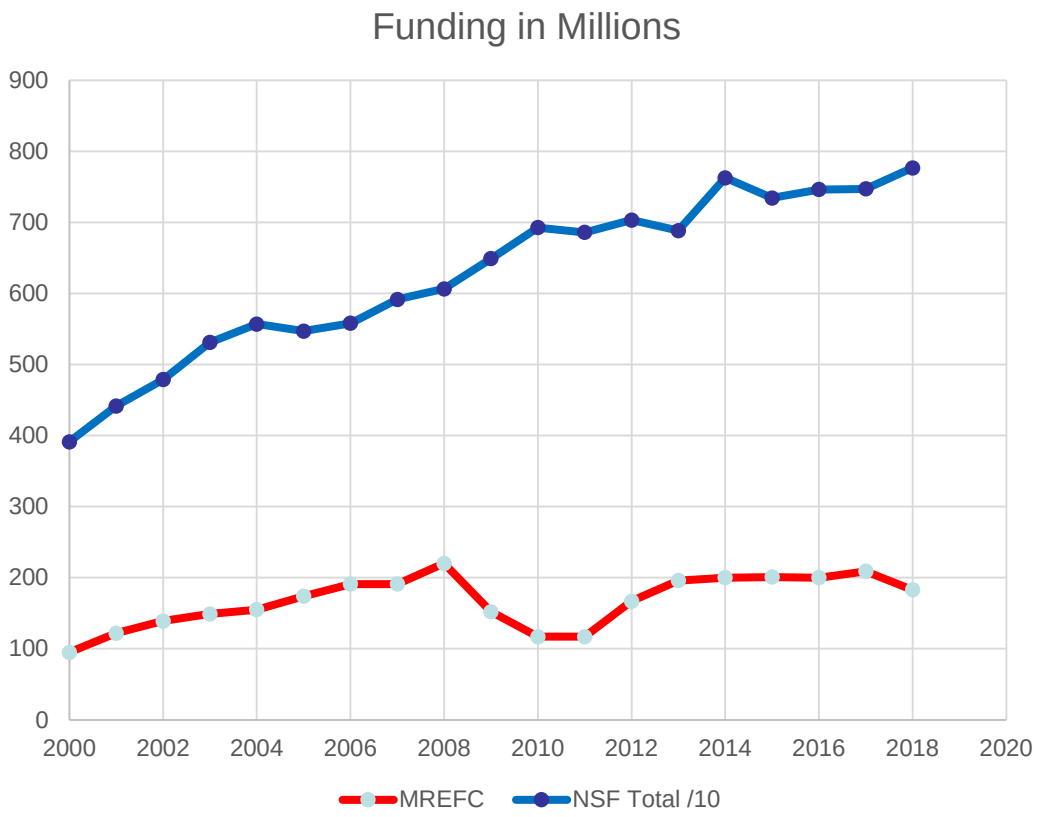
NSF Total: $473M

DOE Total: $168M

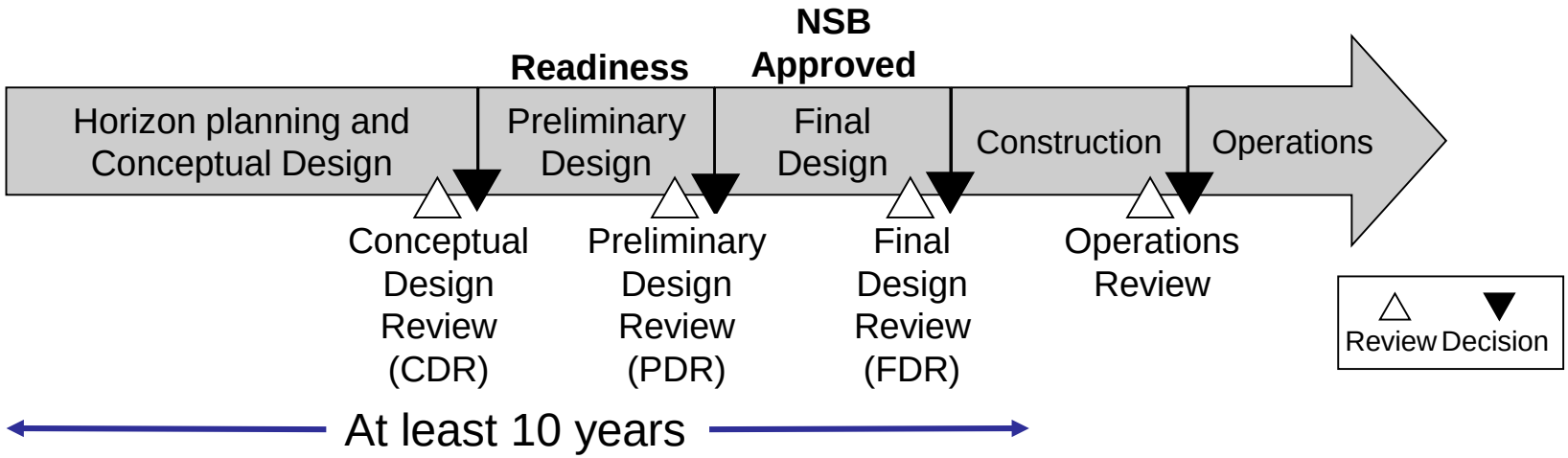
Private: $69M

International Total: Not known

Operations: $63M/year (NSF covers 50%)



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)

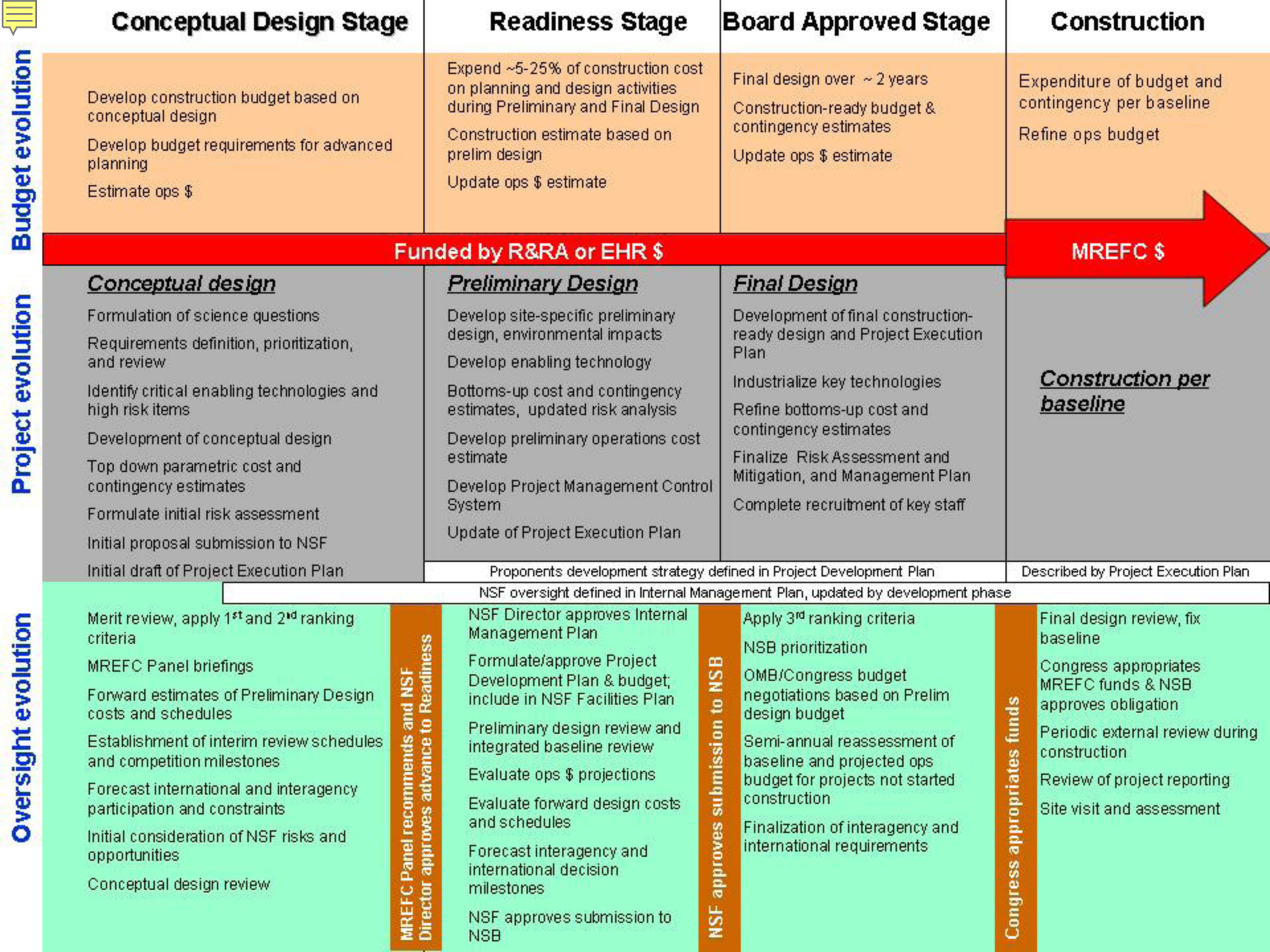
- **SCOPE:** Detailed design that forms basis for bid packages.
- **BUDGET:** Significant proportion of costs based on external data: vendor estimates, quotes; plans for subawardee oversight, project management.
- **SCHEDULE**: Schedule includes vendor information.
- **MANAGEMENT:** Credible project team, MOU's 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


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 $
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
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

What are the steps for Cosmic Explorer?

Horizon planning (3G Design NSF award in 2018) Cosmic Explorer White Paper (3G Design award product) (see WP examples for CMS https://cds.cern.ch/record/2055167?ln=en, and ATLAS https://cds.cern.ch/record/2055248/files/LHCC-G-166.pdf)	3 years
Community endorses the WP (through Dawn meeting?)	½ year
NRC report based on CE WP and GWIC reports	1 ½ years?
MPSAC subcommittee reviews NRC report Physics Division develops written plan for MPS approval NSF Director makes a decision to authorize CD funding	½ year
Conceptual Design period	2-3 years
Preliminary Design period award	2-3 years
NSF approves submission to NSB	½ year
Final Design period NSB prioritization OMB/Congress budget negotiations	2-3 years
Congress appropriates MREFC funding (2030-35)	**Total: 12-15 years**

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)

NSF MREFC Documents

- NSF Large Facility Manual:
  - https://www.nsf.gov/pubs/2017/nsf17066/nsf17066.pdfNSF's Major Facilities Guide (in draft):
  - https://www.nsf.gov/bfa/lfo/docs/Major_Facilities_Guide_2019_Draft_For_Public_Comment_December_2018.pdf

- Describes process steps and expectations in detail, and coordination of processes for:
  - project development by community
  - oversight and review within NSF
  - budget development, request, appropriation, and obligation process.

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
  - R&D and design concepts needs to be developed and re-developed
  - Scientists and funding agencies need to work on a viable plan to support the construction and, also critically important, the operations of these installations

I am looking forward to the next decade of Dawn (or whatever their next name is) meetings!