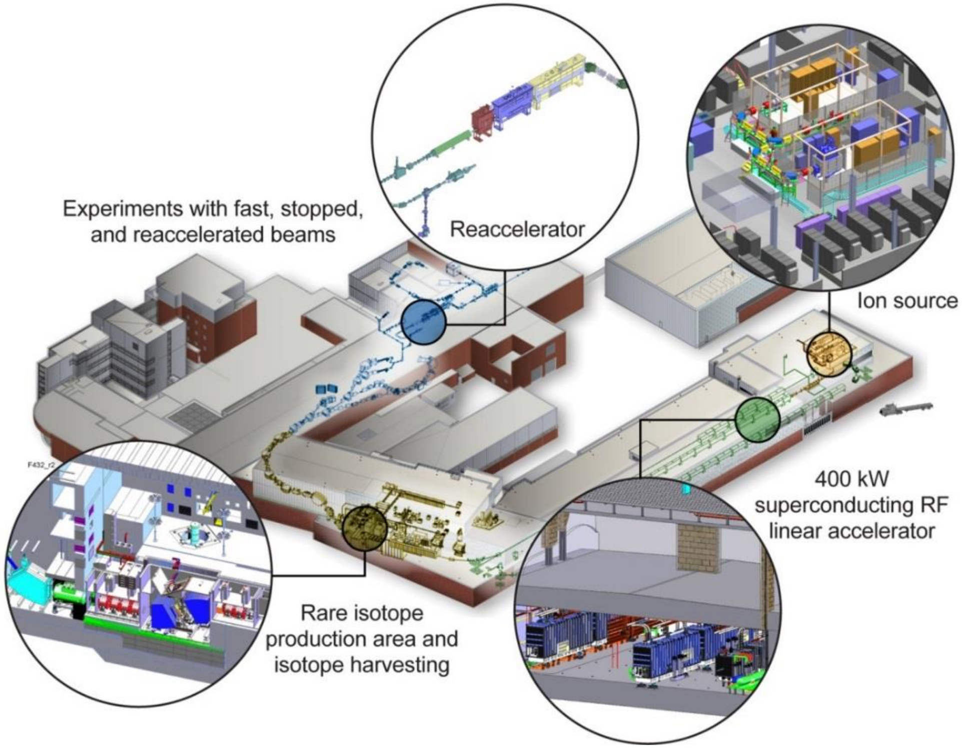
Facility for Rare Isotope Beams (FRIB)

Thomas Glasmacher

Facility for Rare Isotope Beams

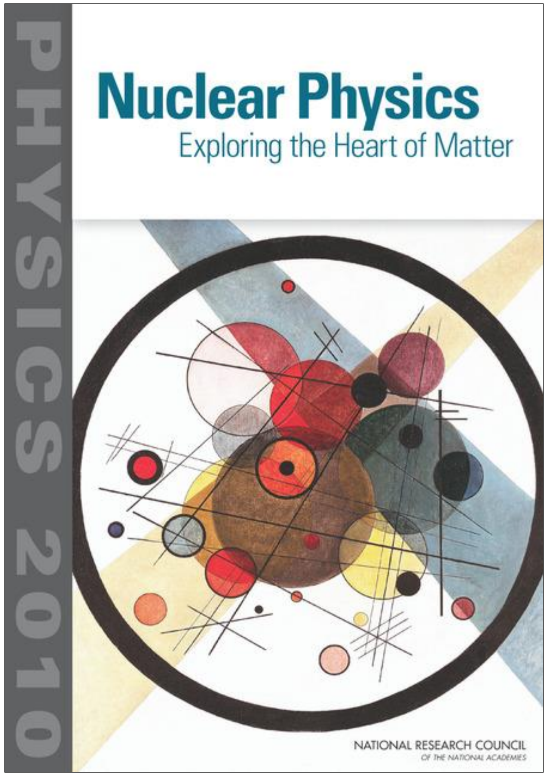
- **A future DOE-SC scientific user facility supporting the mission of the Office of Nuclear Physics (SC-26)**
- **Funded with financial assistance from DOE Office of Science (DOE–SC) with cost share and contributions from Michigan State University (MSU)**
- **Total Project Cost $730M**
  - **DOE share $635.5M**
  - **MSU cost share $94.5M**
  - **MSU contributions $212M in addition to TPC**
- **MSU designs and establishes FRIB to support DOE-SC mission**
- **MSU selected after competitive announcement, which specified**
  - **Field Work Authorization for DOE FFRDC**
  - **Cooperative Agreement for other entity**

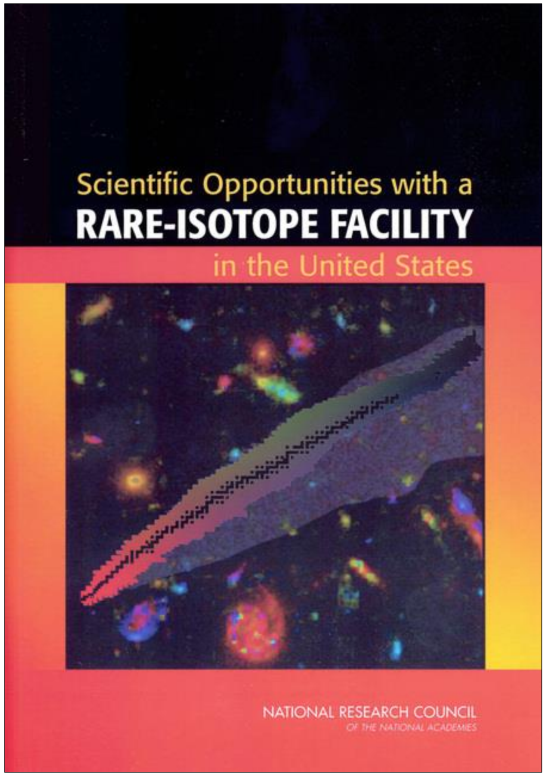


- **Most powerful heavy-ion accelerator yields most rare isotopes, key features:**
  - **400 kW beam power for all ions (5×10^{13} ^{238}U/second)**
  - **Separation of isotopes in-flight**
  - **Fast, stopped, reaccelerated beams**

FRIB Science Endorsed by National Research Council of the National Academies

- **National Research Council Decadal Study on Nuclear Physics Report**
  - **Nuclear Physics: Exploring the Heart of Matter (2013)**
- **National Academies Rare Isotope Science Assessment Committee Report (RISAC)**
  - **Scientific Opportunities with a Rare-Isotope Facility in the United States (2007)**





FRIB Mission and Deliverables Defined by DOE in Funding Opportunity Announcement

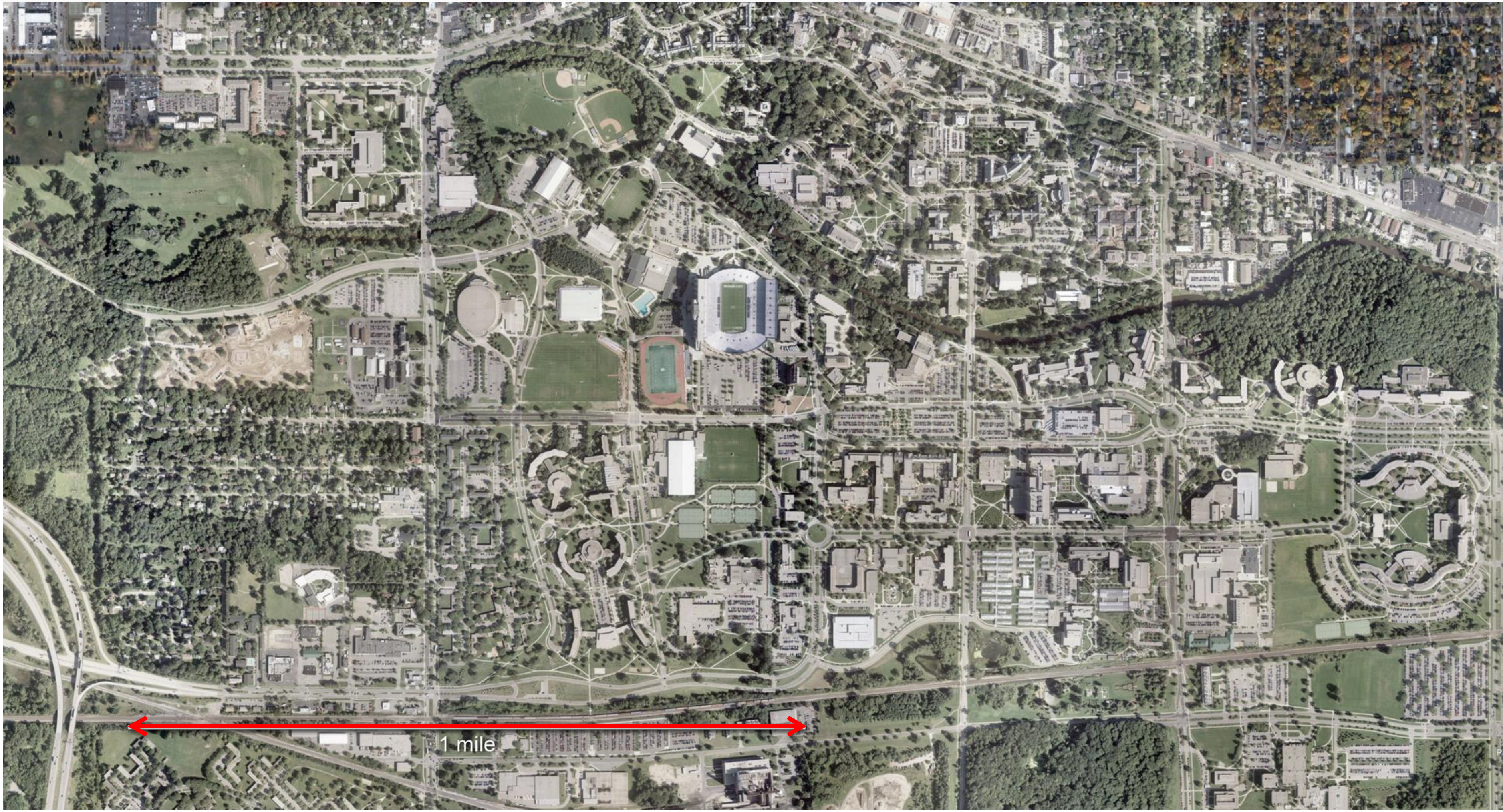
FRIB Mission

- Intense beams of rare isotopes (short-lived nuclei not normally found on earth) are needed to address forefront scientific questions in a wide variety of studies in nuclear structure, nuclear astrophysics, and fundamental symmetries.
- An accelerator facility for rare isotope beams (FRIB) is needed, for example, to understand the origin of the elements and the evolution of the cosmos, and offers a laboratory for exploring the limits of nuclear existence and identifying new phenomena, with the possibility that a more broadly applicable theory of nuclei will emerge.
- Experiments addressing questions of the fundamental symmetries of nature will similarly be conducted at a FRIB because of the ability to create and study certain special, rare isotopes. A U.S.
- FRIB is essential for the Nation to maintain scientific leadership in these fields of study.

FRIB Project Deliverables

- The minimum technical specifications of the FRIB are that the facility be based on a 200 MeV/u, 400 kW superconducting heavy-ion driver linac.
- The initial capabilities of the FRIB should include fragmentation of fast heavy-ion beams combined with gas stopping and reacceleration.
- The technical scope should include necessary facilities and equipment for the establishment and operation of the FRIB, including driver linac and switchyard, target facilities, cryogenics facilities, gas stopper, fragment separator(s), radioactive ion beam (RIB) post accelerator, experimental areas and instrumentation that will allow the community of facility users to shed light on important scientific issues.
- Accommodate a community of 1,000 users

Michigan State University is the “Recipient” of DOE-SC Financial Assistance



Public Research University established in 1855 | $2.3B annual budget | Elected Board of Trustees with authority delegated to President | 5,200 acres | 538 buildings | 12,000 employees | 50,000 students

Long History of Accelerators and Nuclear Science at MSU

- 1958 MSU hires first accelerator expert
- 1961 NSF approves sector focused K50 cyclotron
- 1965 Research with K50; single turn extration
- 1975 NSF approves superconducting cyclotron magnet prototype
- 1977 NSF approves K500 cyclotron
- 1978 NSAC recommends national user facility at MSU
- 1982 Research with stable beams from K500
- 1989 Research with stable beams from K1200
- 1990 Research with fast rare isotope beams from A1200
- 1996 NSF approves coupled cyclotron facility (CCF)
- 2001 Research with fast rare isotope beams from CCF
- 2002 Infrastructure for SRF linac R&D
- 2005 Research with trapped rare isotope beams
- 2006 MSU funds ReA3 reaccelerator project
- 2008 DOE selects MSU to establish FRIB
- FY2017-21 Final NSF 5-year Cooperative Agreement
- FY2021 Managing to early completion
- 2022 FRIB completion

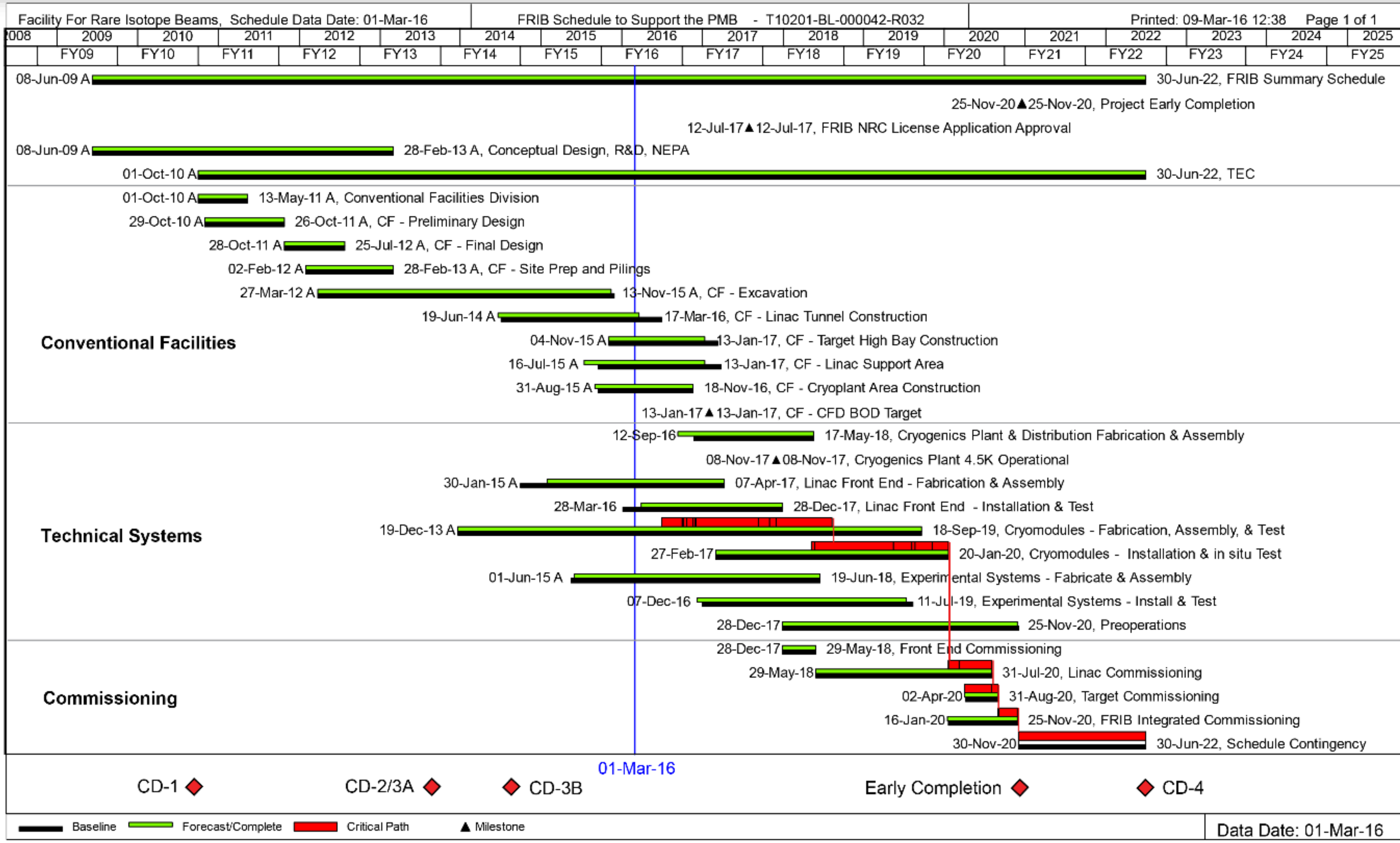
First single-turn extraction cyclotron (1965) → **First superconducting cyclotron (1982)** → **Most powerful heavy-ion accelerator (2021)**

FRIB Project Managed Like All Office of Science Projects

- Project started in June 2009: Cooperative Agreement between DOE-SC and MSU
  - Project delivery per DOE Order 413.3B: Acquisition Executive SC-2 Dr. Patricia Dehmer, DOE-SC Office of Project Assessment reviews, Federal Project Director from SC-Chicago; MSU shares $94.5M in cost and contributes $212M; decommissioning is MSU's responsibility
- CD-1 approved in September 2010: Conceptual design complete
- CD-2 (Performance Baseline) and CD-3a (Start of Civil Construction) approved in August 2013, pending notice to proceed for civil construction upon FY14 appropriation
- Civil construction began March 3, 2014
- CD-3b DOE-SC Office of Project Assessment review in June 2014 to assess readiness for technical construction
- Technical construction started in October 2014

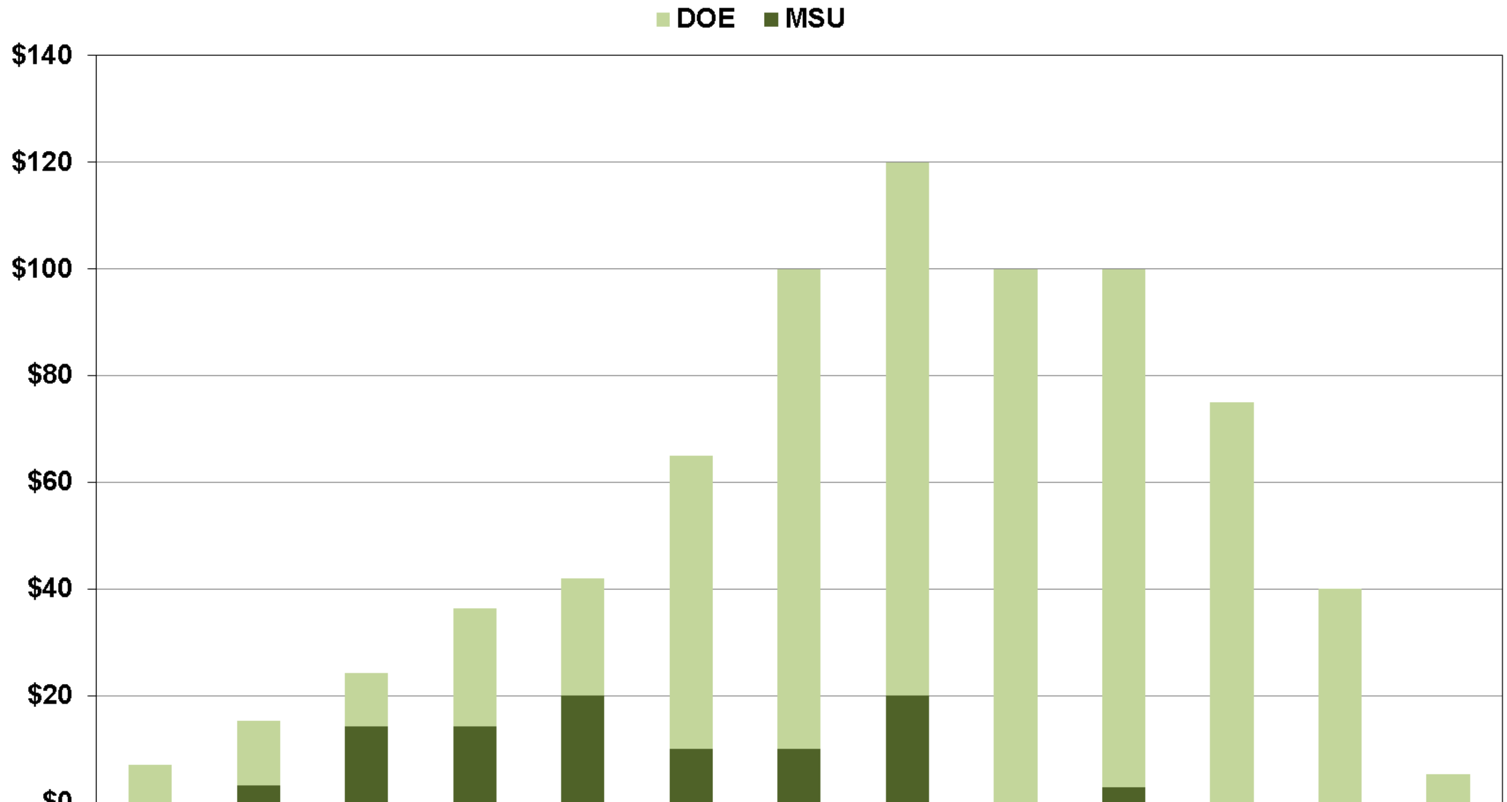
- Managing to early completion in fiscal year 2021
- CD-4 (project completion) is June 2022

FRIB Project is on Schedule



- 58.5% planned complete, 58.9% earned complete
- Managing to early completion in FY2021 (remaining duration 57 months, then have 18 months float to CD-4)
- Civil construction 10.5 weeks ahead of early completion schedule

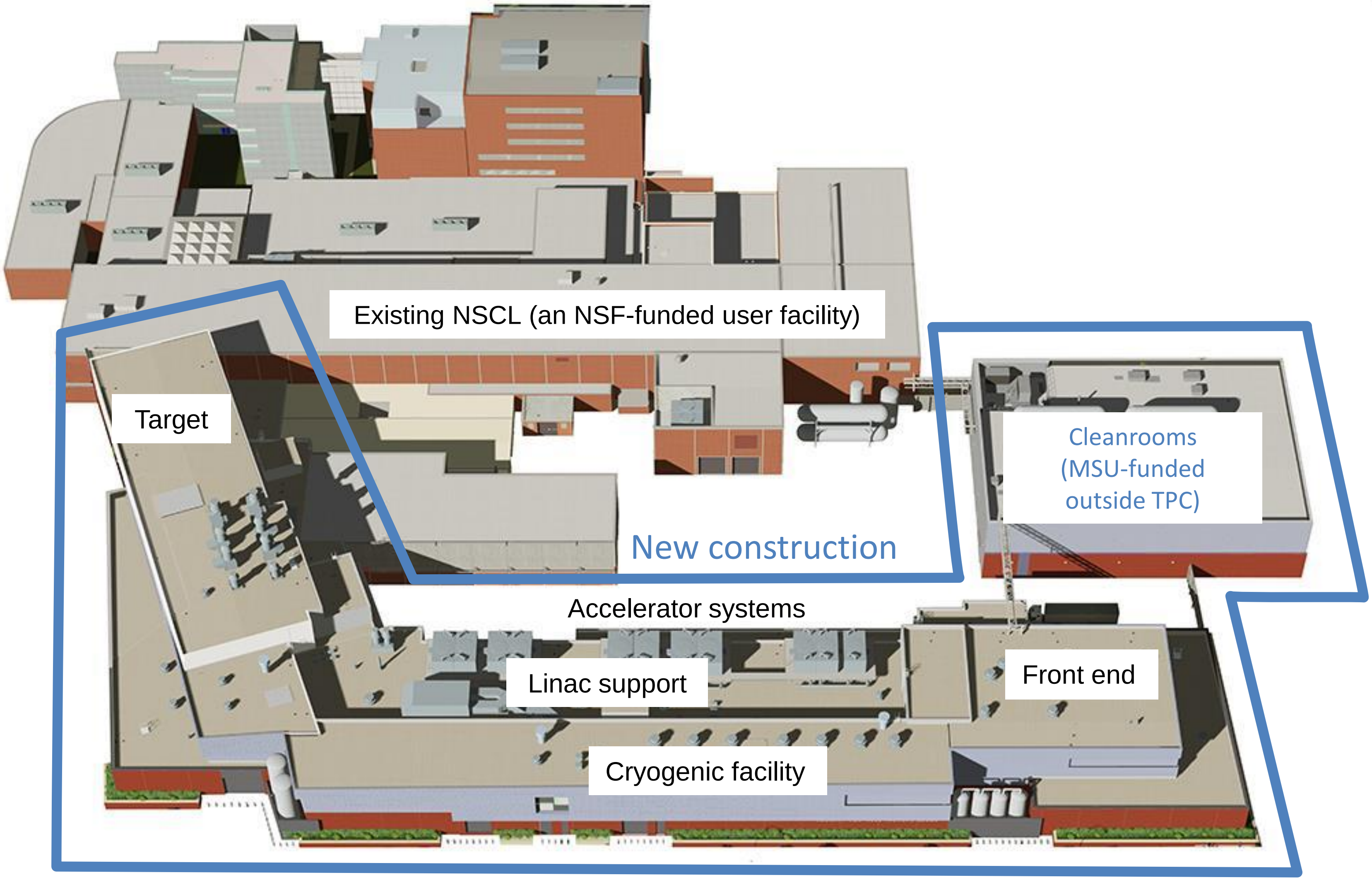
FRIB is Within Budget
Funding Appropriated as Planned in PEP



	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY20	FY21
DOE	$7.0	$12.0	$10.0	$22.0	$22.0	$55.0	$90.0	$100.0	$100.0	$97.2	$75.0	$40.0	$5.3
MSU		$3.2	$14.2	$14.3	$20.0	$10.0	$10.0	$20.0		$2.8			

- MSU advanced FY15, FY16, FY18 cost share to FY14 to enhance project success, this allows civil construction to proceed on technically limited schedule

FRIB Design: Incorporate Existing NSCL User Facility at CD-4



- Design minimizes interruption to user operation and thus to nation's leadership in rare isotope science: Commission FRIB technical systems before stopping NSCL operation

February 2013:
Site Preparation Complete

- 2013 and early 2014, no new starts with federal funds under continuing appropriations resolution
- January 17, 2014: FY 2014 Consolidated Appropriations Act (Omnibus Appropriations) signed Public Law No. 113-76
- Managing constraints, keeping project team together, focusing on design optimization and energy efficiency

March 17, 2014: Ground Breaking

Dr. Michael Knotek
DOE Deputy Under Secretary for Science and Energy

November 2014:
Earth Retention Complete, Tunnel Started

- Guaranteed Maximum Price contract, written at 90% of contractors' bids
- Value proposition to A/E, CM and trade contractors: Follow-on work at MSU and brochure piece
- Best value procurement resulted in national firms with strong presence in Michigan, large regional firms for trade contractors
- Constructive engagement with trade unions

May 2015: Tunnel Partially Backfilled, Surface Building Started

- Design optimization in 2013: Building towards existing structures in direction of the ion beam, rather than away from existing structures as initially planned in baseline schedule

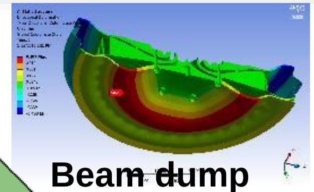
March 2016: Surface Building Partially Complete, Warm Ion Source Moving in

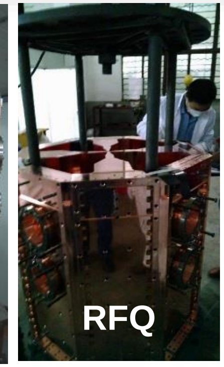
- Ion source moving in 16 months ahead of schedule due to design optimization
- Beneficial occupancy for all civil construction in March 2017

Technical Construction on Track for Early Completion in FY 2021

Cryomodule test
Present

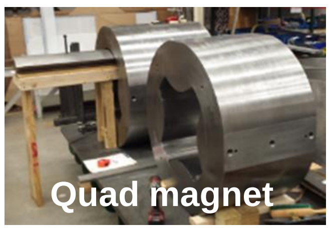
Front end
Q4 2016



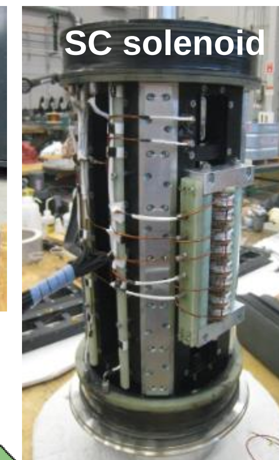


Radio Frequency Quadrupole
Q1 2017

Linac segment 1
Q2 2018

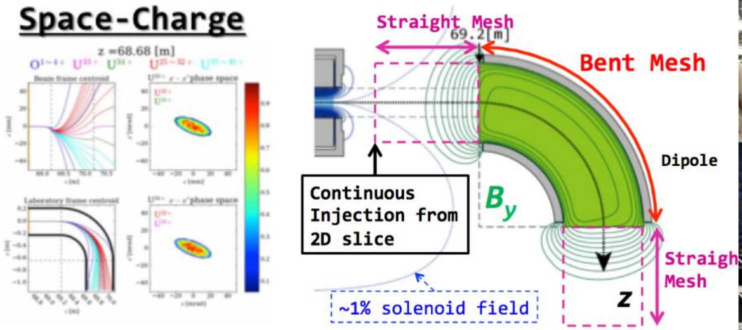


Folding section 1 and stripper
Q1 2019



Linac segment 2
Q4 2019

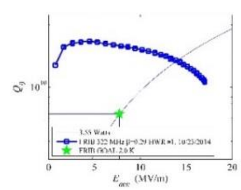
3D Simulation of Dipole Bend with Space-Charge



Folding section 2
Q4 2019

Linac segment 3
Q4 2019

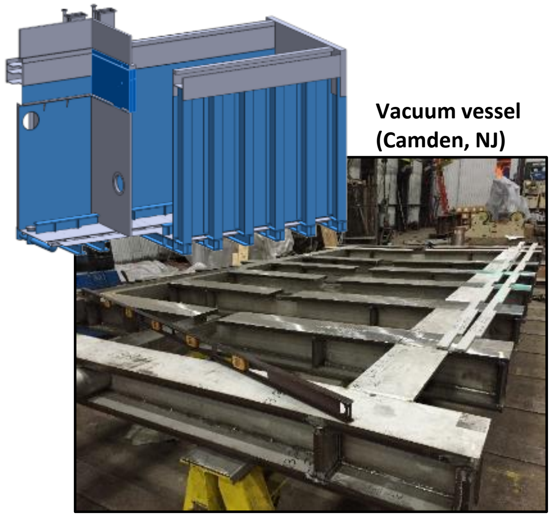
Cavity Q



Target
Q1 2020

Delivering one-of-a-kind Procurements: Engaged Vendor Management is Key

- Shield glass window (Kent, WA)
- ASD source wire (Waterbury, CT and Shrewsbury, MA)
- Bridge crane (Shore View, MN
- Hot-cell machine lift (Milwaukee, WI)
- Chambers (Yuma, CA)
- Chambers (Williston, FL)
- Temp monitors (Westerville, OH)
- Level monitors (Oak Ridge, TN)



Vacuum vessel (Camden, NJ)

Warm helium compressor skids (Hilliard, OH)

4.5 K cold box (Tulsa, OK)

SRF cavity (Brownsburg, IN and Medford, NY)

Cryomodule (Merrill, MI)

Multi-layer insulation (Middlesex, VT)

RF pickup cables (Wallingford, CT)

- Value proposition to technical one-of-a-kind vendors is difficult: Mostly non-catalog items, no follow-on work, limited budget and pushing schedule
- Many smaller (less than 100 employees) supplier

Working with the Best in the Nation and World Where Special Expertise Exists

- Argonne National Laboratory
  - Liquid lithium charge stripper; stopping of ions in gas; fragment separator design; beam dynamics; SRF
- Brookhaven National Laboratory
  - Radiation-resistant magnets; plasma charge stripper
- Fermilab
  - Diagnostics
- Jefferson Laboratory
  - Cryogenics; SRF
- Lawrence Berkeley National Laboratory
  - ECR ion source; beam dynamics
- Oak Ridge National Laboratory
  - Target facility; beam dump R&D; cryogenic controls
- Stanford National Accelerator Lab
  - Cryogenics
- Sandia
  - Production target

- Budker Inst. of Nuclear Physics (Russia)
  - Production target
- GANIL (France)
  - Production target
- GSI (Germany)
  - Production target
- INFN Legnaro (Italy)
  - SRF
- KEK (Japan)
  - SRF technology; SC solenoid magnets
- RIKEN (Japan)
  - Charge strippers
- Soreq (Israel)
  - Production target
- Tsinghua University & CAS (China)
  - RFQ
- TRIUMF (Canada)
  - SRF; beam dynamics

FFRDCs provide good value where special expertise exists

Engaging right people is key to success

Committed and Capable Staff is Key to Delivering Technical Scope

- Technical construction
  - No complete set of functional and operational requirements, parameter list instead
  - Unique technical expertise required, maybe only a few people in the world who have done it
  - Key for success is committed and capable staff
    - Many imagine they can deliver, not all actually can
    - Staff needs to be self-aware (know what you do not know), humble (willing to learn), agile (make timely decisions), result-oriented (rather than ideological) and optimize for the project (rather than for themselves)
- Civil construction is a well-established industry
  - Established practices, shared standards, many "suppliers"
  - A/E documents a complete, reviewed set of requirements; established RFI process to resolve issues

High-Quality Project Advisory Committees Critical to Success

- Busy, senior people are willing to give their time if the feel they make a difference and we are willing to learn
  - ESS Director, LIGO Director (retired), SC Director (retired), SC Level 4 FPD (retired), many active practitioners
- We have not done what we plan to do
- We must be humble enough to learn
- Learning for our context from others who delivered one-of-a-kind projects in their contexts
  - Listen to the stories
  - Abstract away context-specific distractions
  - Distill the essence
  - Convolute essence with our contexts
  - Learn, adjust and act

Project Management for FRIB is People Management with Constraints

- Constraints: cost, scope, schedule, quality, safety
- Scope is ensured by qualified, committed staff
  - Key question: Will staff deliver scope that works?
  - Reviews help with transparency and are necessary but not sufficient; project manager must judge her/his staff's ability
- Schedule and cost are more transparent than scope
  - Must drive schedule; must manage cost
  - Scope issues can drive schedule delay resulting in cost overruns
    - Apparent failure cost overrun, root-cause scope issue

FRIB Project Management Approach

- Schedule has all the work: drive schedule, manage cost
- Manage to leading indicators
  - Orders placed, equipment installed, …
  - Manager have next steps in their heads, know what’s going on
- Communicate with full transparency, we are all in the same boat: Lists, trackers, hallway displays
- Enable and demand purposeful action to move forward
- Avoid non-value added work
- EVMS (certified to ANSI 748) is cost accounting tool to communicate project performance to stakeholders. Consider
  - Latency
  - EVMS does not protect scope

DOE-External Regulations

- External regulations not designed for DOE projects
- External regulations not always integrated with each other
  - Overlaps and holes
  - MSU needs to work this out and decide on approach and document. Local regulators will not be able to provide definitive interpretation, they may share their practice
- Requirements-based management pays off
  - Investigate applicability of purported regulations, document decision and rationale
- External regulation may be quiet on certain important issues, recipient needs to mitigate this. FRIB uses DOE Orders for reference as they provide integrated sets of requirements.
  - Integrated Safety Management (DOE O 450.2), Quality (DOE O 414), Environmental Management (DOE O 450.1)
    - Incorporate into registered OHSAS 18001, ISO 9001, ISO 14001 programs and have audited by external registrars
  - Natural phenomena hazards (DOE O 420.1C) for accelerators
- Manage risk that external regulators may overstep their authority
  - Advice versus direction
  - Invoke disambiguation process for federal agencies

Delivering Project for DOE with DOE-External Regulators

- DOE needs assurance that MSU remains in good standing with external regulators so that mission is not compromised
  - FRIB reports all MSU regulations issues to DOE FPD to keep trust
- DOE needs assurance that external regulators provide reasonable requirements so that mission is not compromised
  - Worker Safety: 10 CFR 851 vs. Michigan OSHA
  - Nuclear Safety: 10 CFR 830 vs. 10 CFR 20 (NRC)
  - Much of the CFR language identical, we wrote cross walks
- External regulators with at times limited experience – MSU needs to compensate with experts, e.g. for accelerators
  - Nuclear Regulatory Commission regulates exposure to humans and radioactive material leaving accelerator
  - State of Michigan regulates accelerator
    - Hold our own Accelerator Readiness Review, report to MSU President's Office

We Must Meet Expectations of All Stakeholders

- DOE
  - Has established project delivery approval sequence (CD-1, 2, 3, 4)
  - Has oversight expectations (Office of Project Assessment)
- MSU's governing body established by Michigan's constitution
  - Elected Board of Trustees for MSU)
  - Has established civil construction delivery approval sequence (Step 1, 2, 3)
  - Has oversight expectations (Vice Presidents and President)
- Congressional appropriations professional staff have project delivery expectations and manage through DOE Acquisition Executive FRIB, under financial assistance
  - FRIB is now a congressional line item
  - Followed "no new construction starts" under Continuing Resolution
  - Follows intent of DOE O 413.3 (the order does not apply to financial assistance)
- Financial Assistance Regulations
  - Office of Management and Budget
    - Issues Circulars to standardize Financial Assistance Practices
      - 2 CFR 200 (super circular, just over 100 pages)
  - Awarding agencies implement Circulars in their regulations
    - (10 CFR 600, 2 CFR 900 for DOE)

1354 Users Ready for Science and Excited About FRIB

www.fribusers.org

- Users are organized as part of the independent FRIB Users Organization (FRIBUO)
  - Chartered organization with an elected executive committee
  - 1,354 members (98 U.S. colleges and universities, 12 national laboratories, 50 countries) as of February 2016
  - 19 working groups on instruments
  - Annual meetings

- Science Advisory Committee
  - Review of equipment initiatives (February 2011)
  - Review of FRIB integrated design (March 2012)
  - Review of equipment working group progress (October 2013)
  - Review of experimental equipment plans (March 2015)
- FRIB enables scientists to make discoveries

Summary

- FRIB will be a DOE-SC scientific user facility supporting the Office of Nuclear Physics mission
- FRIB on track (59% done), within budget, managing to early completion in FY 2021
- FRIB being established with DOE financial assistance by Michigan State University with MSU cost share under DOE-external regulations
- Project Management is people management with constraints
- Capable and committed staff is critical to FRIB's success
- Managing to leading indicators, driving schedule, minding budget and performance comes