Fusion Engineering Development

Scenarios - First Cut

D. Berwald

M. Abdou

Finesse Project Meeting, July 12, 1984

MOTIVATION

- The FINESSE program has several goals:
  - identify the nuclear testing issues which must be resolved in the development of components for commercial-scale fusion reactors.
  - assess the fusion, nuclear, and non-nuclear facilities which might be used to address these issues.
  - learn from the development experiences of similar technologies (fission, aerospace).
  - develop an informed opinion regarding the interactions between risk, schedule, and cost in progressing towards an engineering development phase for fusion.

- The scenario development task will be used to address the last of the above goals by providing a framework to integrate ongoing FINESSE activities:
  - issues/failure modes.
  - test module designs/engineering scaling activities.
  - test facilities assessment.
  - test matrix development.
  - component reliability growth studies.

STATUS/PLANS

- Initial phase of activity started July 5.
- Presentation to FINESSE advisory committee at Jackson Hole meeting in August. Rationale for narrowing down to a limited number of scenarios (hopefully, four major scenarios).
- Further development for presentation at October workshop.
- Final scenarios developed during FY'85 study will include full logical development.

SCOPE

- Pathways to focus upon key fusion facilities required to develop a given fusion reactor concept through a "demonstration reactor capability."
- Both high and low fluence Nuclear Test Facility options will be considered as applicable.
- Tokamaks and Tandem Mirrors will be considered as both the test facilities and the concept to be developed.
- Scenarios with and without an "FMIT-like" capability will be considered.
- Estimates of the required numbers of tests, test durations, and operational availabilities will, ultimately, be included.
- Rough cost estimates for facilities and their operating costs will be developed.
- International scenarios will be a subset of U.S. scenarios - the expensive ones.

DESCRIPTIONS OF FUSION DEVELOPMENT PATHWAY ELEMENTS

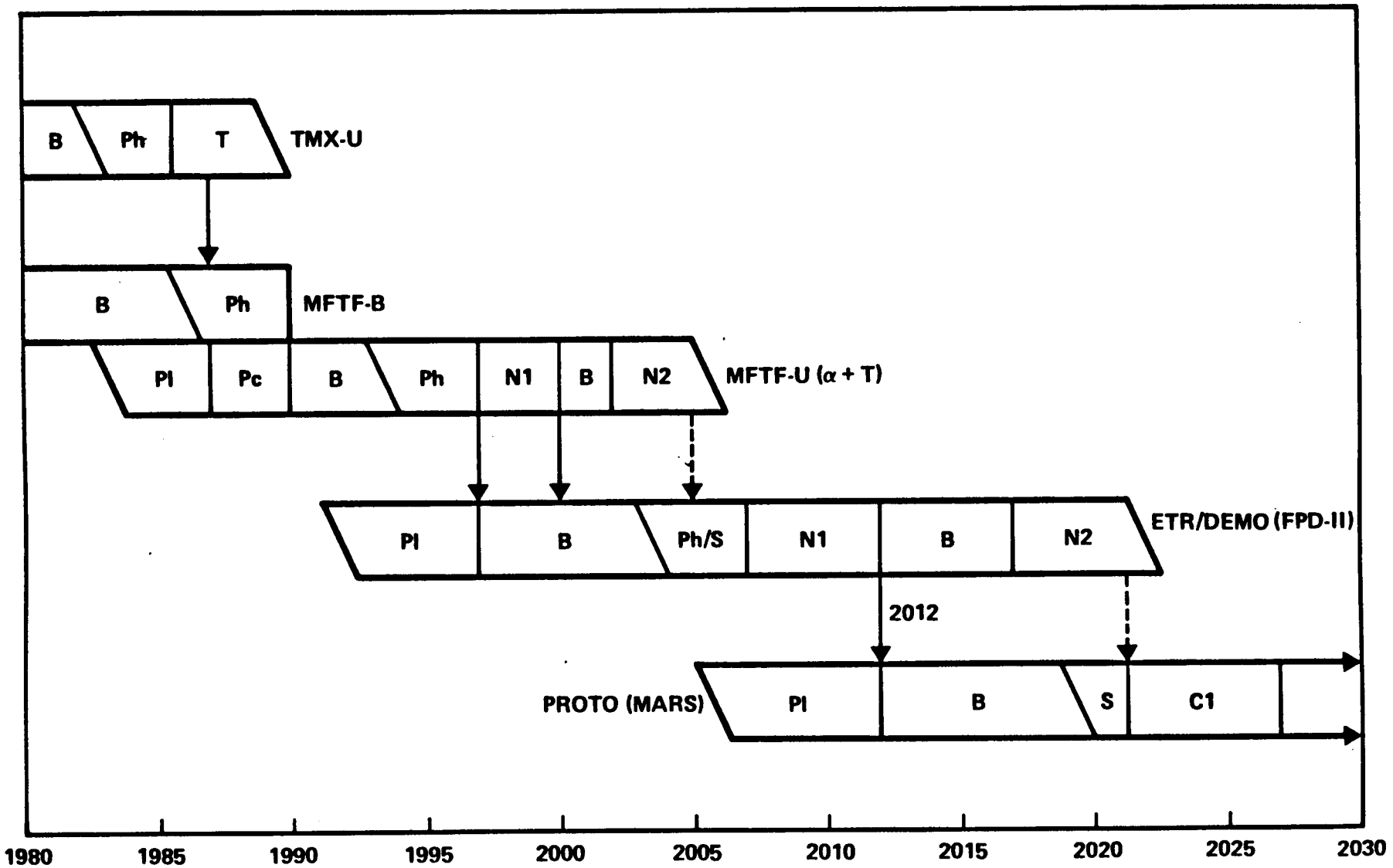
	Ignition/Burn Physics ~~(Physics)~~	Nuclear Test Facility (NTF)	Engineering Test Reactor (ETR)	Engineering Demonstration Reactor (DEMO)
Mission	~~Develop understanding of~~ burning plasma operation and optimization	Test and develop nuclear components	Test and develop all reactor relevant components	~~Provide an engineering~~ demonstration of ~~the technology~~ prototypical system operation at reasonable availability
Description	Configuration relevant to resolve long pulse plasma physics issues	Configuration relevant to nuclear component testing. Capability for several test articles	Fully integrated environment suitable for testing majority of interactive effects	Nearly all systems prototypical, but smaller than full scale commercial
Minimum Fluence Goal	Negligible	~~Hundreds of hours per yr at ~ 1 MW/m²~~ > 1 MW·y/m²	> 3 MW-yr/m²	> 5-6 MW-yr/m²
Availability Goal	~~Negligible~~ Low	Tens of runs per year, days each run	Ultimately ~ 30%	Ultimately ~ 50%
Risk/ Schedule	Risk can be high. Should be first facility in path	Risk as a neutron provider ~~must~~ should be low. Test article risk can be higher	Only test articles can be high risk	Only high fluence tests (>5-6 MW-yr/m²) can be risky
Facility Examples	TFCX, LITE, MFTF-α	MFTF-α + T, TDF, FED-R, NTF	INTOR, FPD, NET, FER	STARFIRE DEMO

OTHER BEASTS IN THE FOREST

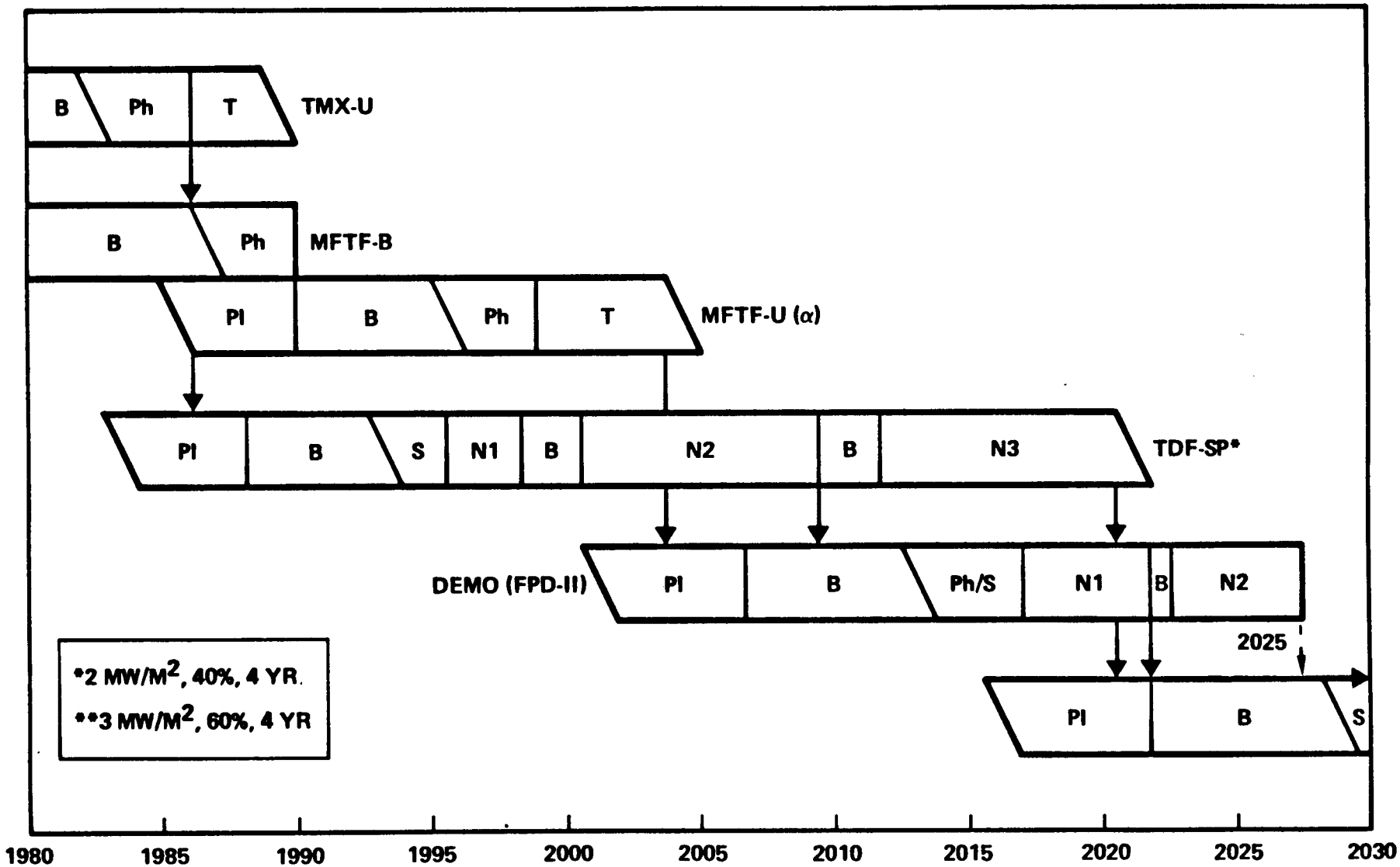
- ETR/DEMO - an advanced ETR with prototypical components that is operated in two stages.
  - high fluence test phase
  - demonstration phase (possibly upgrade)
- NTF/ETR - fully integrated environment excepting the physics operating mode.

Previous Examples

Baseline Tandem Mirror Development Pathway
(MFTF-α + T ⟶ FPD-II)



Alternate Tandem Mirror Development Pathway D
(MFTF-α + TDF-SP ⟶ FPD-II)

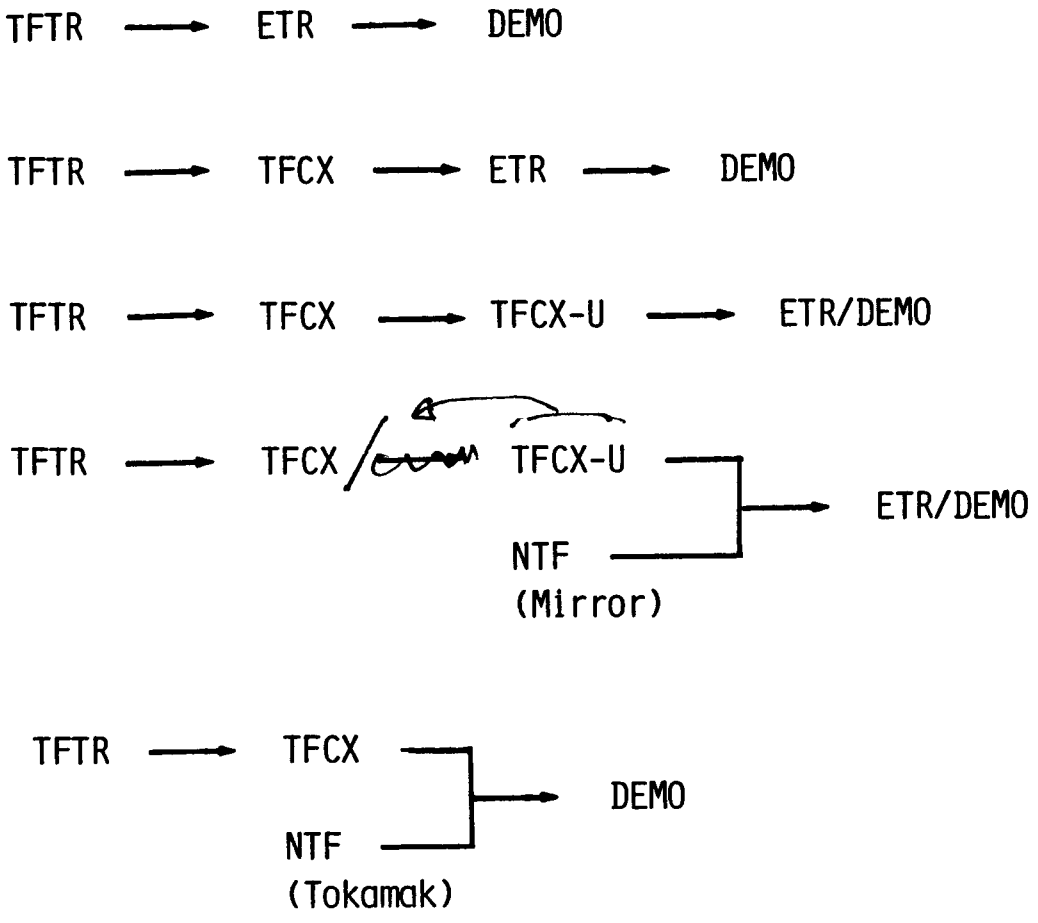


Development Pathway Comparison

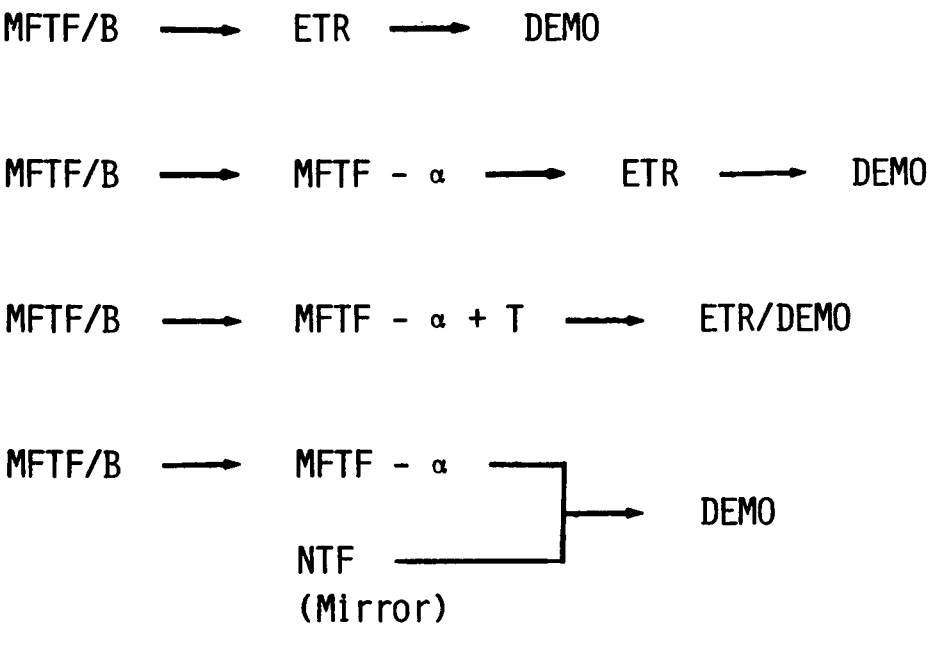
DESCRIPTION		BASELINE	A	B	C	D
		α + T → FPD-II	B + T → FPD-I	α → FPD-II	MFTF-B → FPD-I	α + TDF-SP → FPD-II
RISK	PHYSICS RISK	MODERATE – α, BUT NO MFCD PRIOR TO DEMO	MODERATE – NO α, BUT MFCD	MODERATE – SAME AS BASELINE	MODERATE – NO α, BUT MFCD	MODERATE – SAME AS BASELINE
	NUCLEAR RISK	MODERATE – NO HIGH FLUENCE TEST PRIOR TO DEMO	MODERATE – SAME AS BASELINE	HIGH – NO NUCLEAR TEST PRIOR TO DEMO	HIGH – NO NUCLEAR TEST PRIOR TO DEMO	LOW – HIGH FLUENCE TEST PRIOR TO DEMO
	INTEGRATION RISK	LOW – REACTOR RELEVANT PHYSICS AND NUCLEAR EARLY IN PROGRAM	MODERATE – NO REACTOR RELEVANT PHYSICS UNTIL ETR/DEMO	HIGH – VERY LARGE STEPS	HIGH – VERY LARGE STEPS	LOW – BETTER THAN BASELINE
	FLEXIBILITY	HIGH – REASONABLE SLIPPAGE FOR α+T AND FPD-II NUCLEAR FAILURES	MODERATE – GOOD NUCLEAR FLEXIBILITY	LOW – ESPECIALLY AFTER ETR/DEMO N2 PHASE	LOW – SAME AS FOR ALTERNATE B	MODERATE – LIMITED DUE TO FLUENCE REQUIRED
FUNDS REQUIRED	NEAR TERM	MODERATE – α+T IN 1987, FPD-II IN 1997	HIGH – B+T IN 1987, FPD-I IN 1990	LOW – α IN 1990, FPD-II IN 1999	MODERATE – FPD-I IN 1990	HIGH – TDF-SP IN 1998, α IN 1990
	LONG TERM	LOW – SHORT DEV. PATH, NO UPGRADES ETR/DEMO LEVEL	MODERATE – SHORT DEV. PATH, BUT ETR/DEMO	MODERATE – EFFICIENT, BUT LONG DEV. PATH	HIGH – LONG PATH AND ETR/DEMO UPGRADE	MODERATE – SAME AS ALTERNATE B
SCHEDULE	DEMO OPERATION DATE	2007 – HIGH FLUENCE NUCLEAR DEMONSTRATION BEGINS	2005	2016	2013	2016
	PROTO OPERATION DATE	2020	2017 – EARLIEST	2029	2026	2028

Manpower Resources Utilization

POSSIBLE TOKAMAK DEVELOPMENT SCENARIOS



POSSIBLE TANDEM MIRROR DEVELOPMENT SCENARIOS



SUMMARY

- Several scenarios have been proposed and will be compared at the August meeting.

- It is expected that the overall number of permutations will be reduced.

- Many factors will be considered in generating the overall logic/timing.