ARIES-RS/AT, FIRE and ITER

Advanced Tokamak Regimes

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for the National FIRE Study Team

Summary

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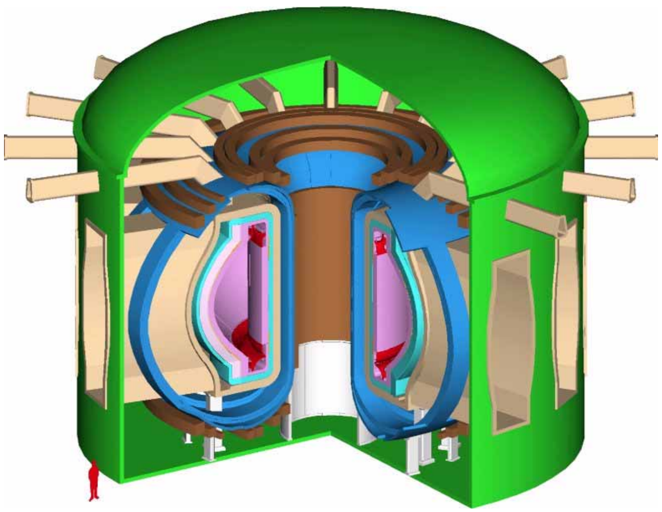
http://fire.pppl.gov

A Decade of Studies has Identified the Requirements for Attractive Fusion Power

Fusion Power Plant
ARIES-AT



Fusion Power 1,800 MW
Plasma Volume 350 m^3

Advanced Tokamak Features

- Self heated by fusion products (~90%)
- Smaller size
  - Improved confinement (reduced turbulence)
- High fusion power density for economics
  - $\sim p^2 \sim \beta^2 B^4$ ($\beta_N > 4$)
- Efficient steady - state operation
  - self generated confinement magnetic field (bootstrap current) (~90%)

- **A burning plasma experiment needs the capability to explore advanced tokamak operation**

FIRE will Emphasize Advanced Tokamak Goals

Burning Plasma Physics

Q	~ 10 as target, ignition not precluded
$f_\alpha = P_\alpha/P_{heat}$	~ 66% as target, up to 83% at Q = 25
TAE/EPM	stable at nominal point, able to access unstable

Advanced Toroidal Physics

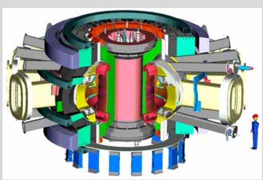
$f_{bs} = I_{bs}/I_p$	~ 80% (goal)
β_N	~ 4.0, n = 1 wall stabilized

Quasi-stationary Burn Duration (use plasma time scales)

Pressure profile evolution and burn control	> 10 τ_E
Alpha ash accumulation/pumping	> several τ_{He}
Plasma current profile evolution	2 to 5 τ_{skin}
Divertor pumping and heat removal	several $\tau_{divertor}$

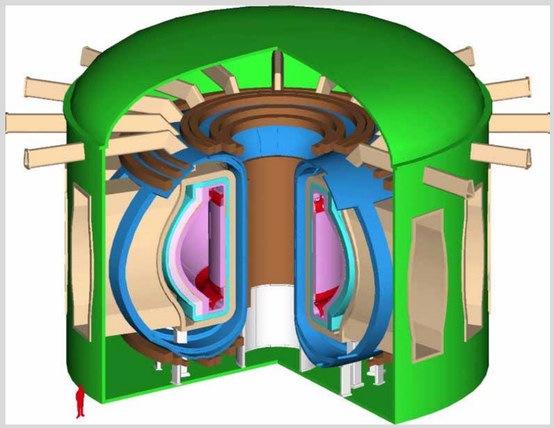
Steps to a Magnetic Fusion Power Plant

FIRE



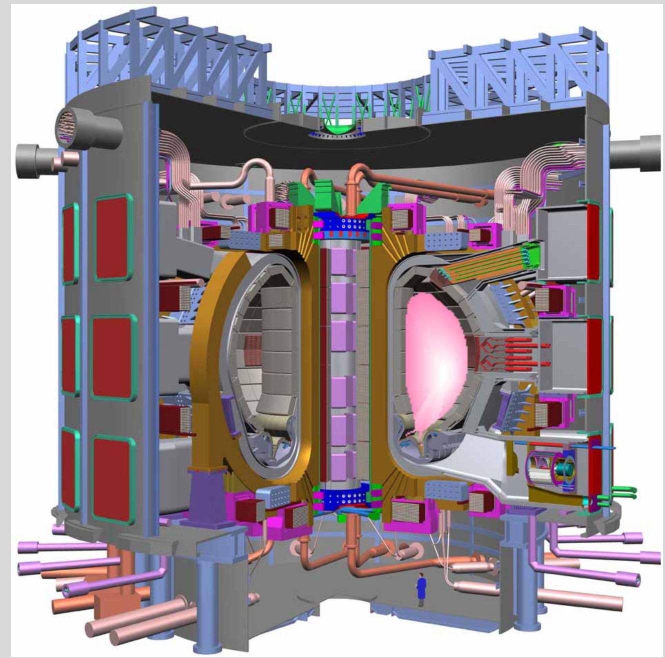
150 MW
27 m^3

Fusion Power Plant
ARIES-AT



1,800 MW
350 m^3

ITER

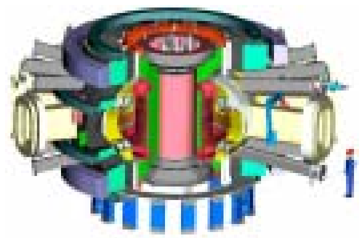


500 MW
840 m^3

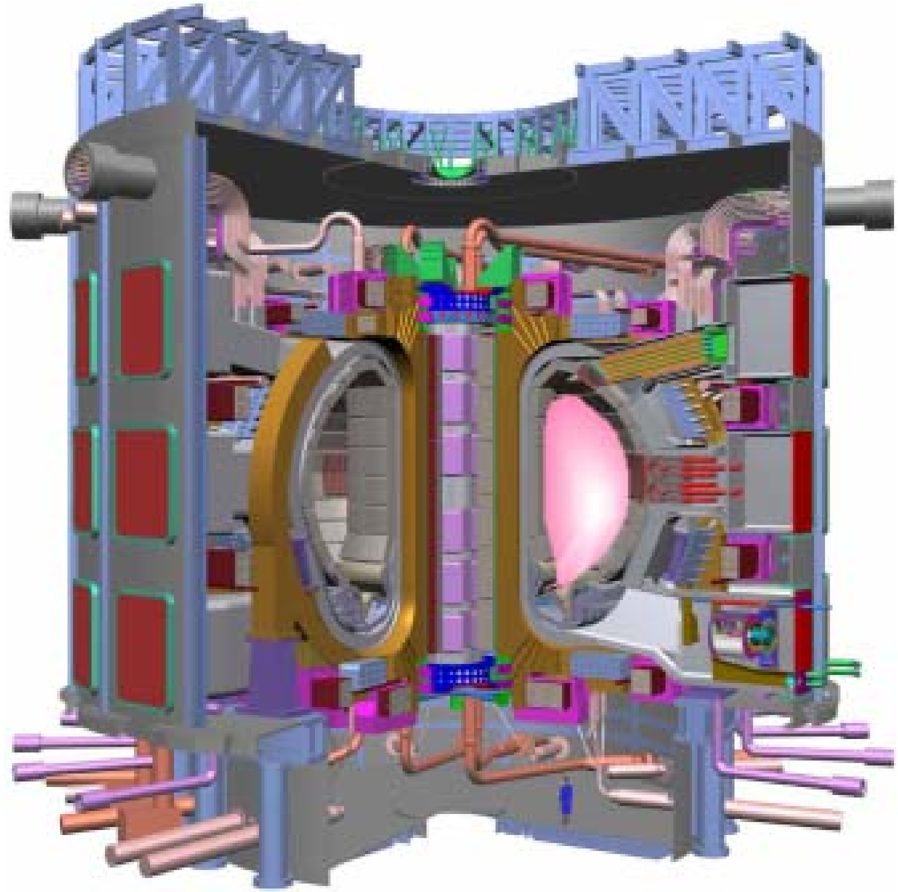
- A decade of studies has led to ARIES-AT as the vision for attractive fusion power.
- A burning plasma experiment is the next step in magnetic fusion research.
- FIRE and ITER are attractive options for a burning plasma experiment.

ITER and FIRE are Each Attractive Options (FESAC)

Primary Burning Plasma Experiments (same scale)



FIRE ($ 1.2B - 1.4 ktonne)



ITER ($ 5B - 19 ktonne)

Conventional Operation

Q ~ 10 @ 86% J(r) equilibration
(FIRE and ITER)

Advanced Operation

Q ~ 5, f_{bs} ~ 80%, β_N ~ 4 @ 98% equil.
(FIRE)

Q ~ 5, f_{bs} ~ 50%, β_N ~ 3 @ 99.9% equil.
(ITER)

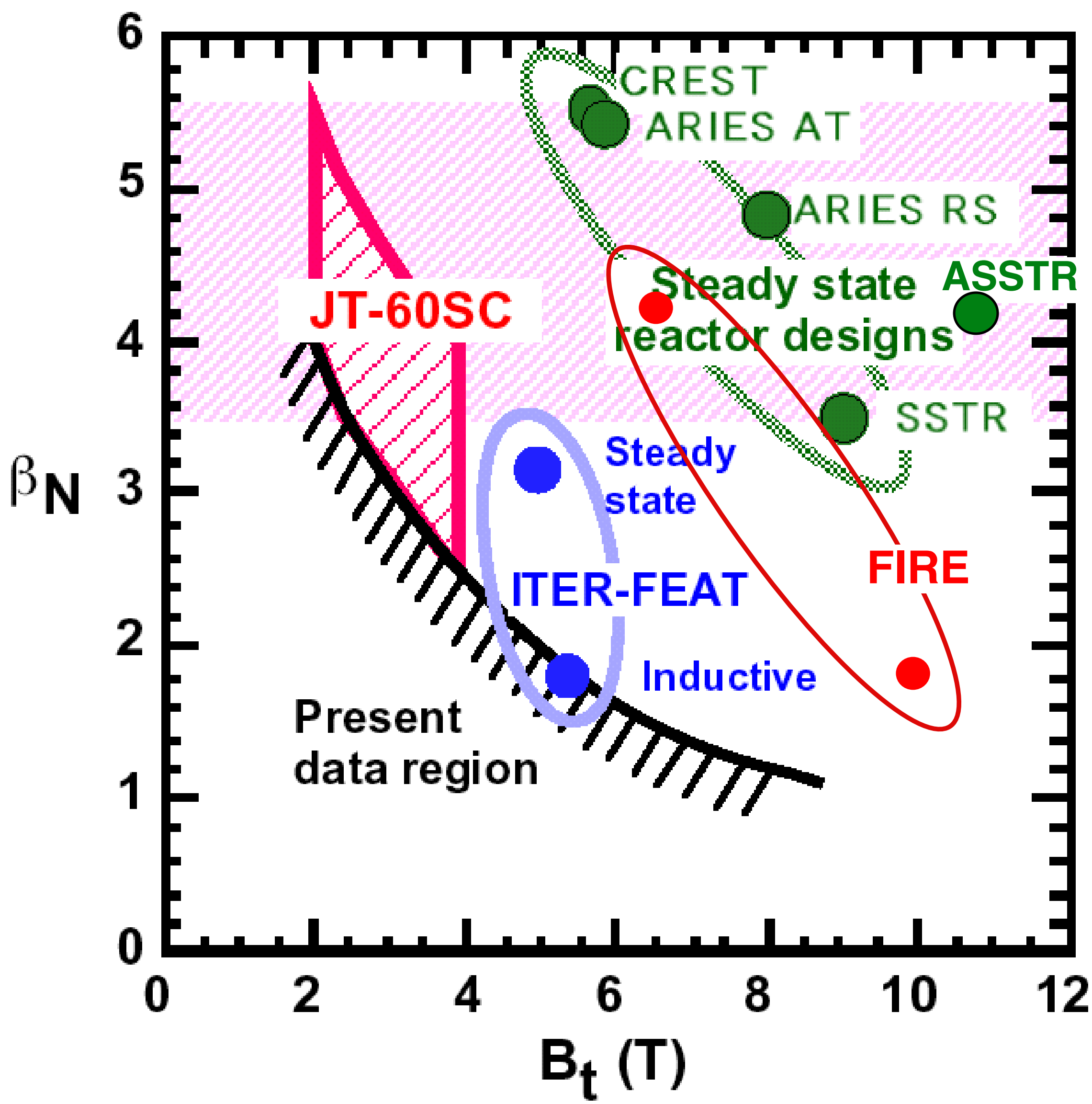
A strategy that allows for the possibility of either burning plasma option is appropriate. (FESAC)

FIRE Would Test Advanced Physics for ARIES-RS

	ITER	FIRE	ARIES-RS
κ_x plasma elongation	1.85	2.0	2.0
δ_x plasma triangularity	0.49	0.7	0.7
Divertor Configuration	SN	DN	DN
β_N, normalized beta, AT	~3	~4	4.8
Bootstrap fraction, AT	50	80	88
B (T)	5.3	10	8
R (m)	6.2	2.14	5.5
Fusion Core Mass, tonne	19,000	1,400	13,000
Plasma Volume, m^2	840	27	350
P_{fusion}(MW)	400	150	2170
P_{fusion}/Vol (MW/m^3)	0.5	5.6	6.2
Neut Wall loading (MW/m^2)	0.57	2.7	4
P_{loss}/ R_x	20	20	100
Divertor Target material	C(W?)	W	W
$Q = P_{fus}/P_{ext}$ Conventional	10	10	n.a.
$Q = P_{fus}/P_{ext}$ Advanced Tok	5	5	27
Burn Time			
seconds	400 - 3,000	20 - 40	20,000,000
Current Profile Equilb,%	86 – 99.99	86 - 98	100

FIRE can Access Regimes of Interest to Advanced Reactors

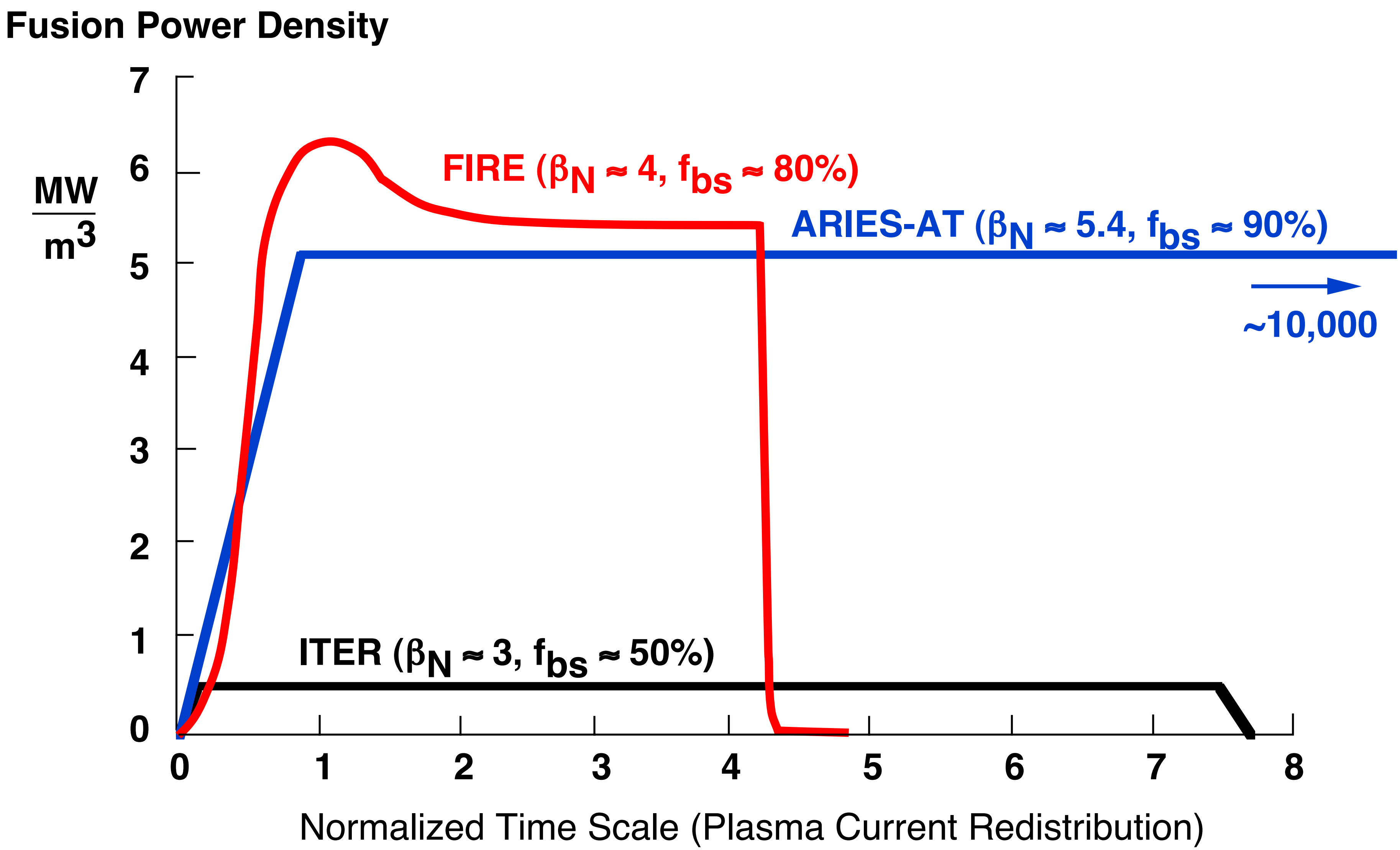
- Reactor studies ARIES in the US and CREST/SSTR in Japan have determined the requirements for an attractive fusion reactor.
- Present tokamak results are far from the attractive reactor regime.
- The present ITER-FEAT design **does not** access the attractive reactor regime.
- The present FIRE design **does** access the attractive reactor regime.



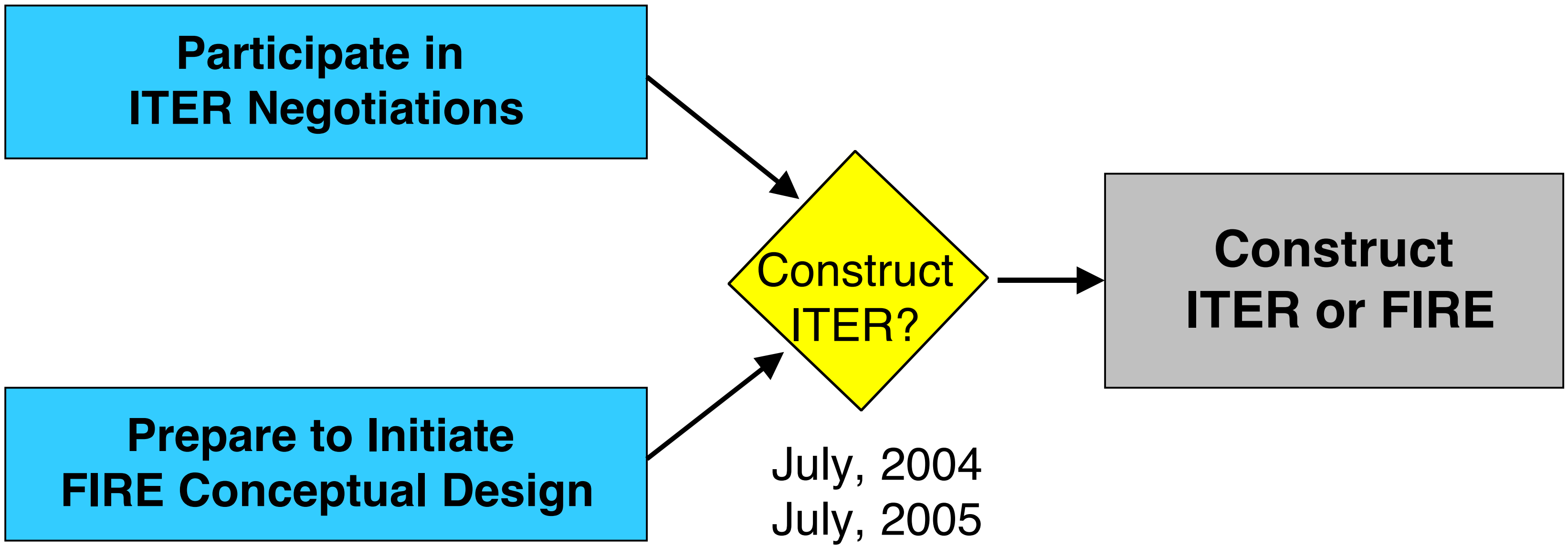
Original figure (without FIRE points) from JT60-SC presentation at IAEA 2002 (Lyon)

FIRE_JT60SC_at_range

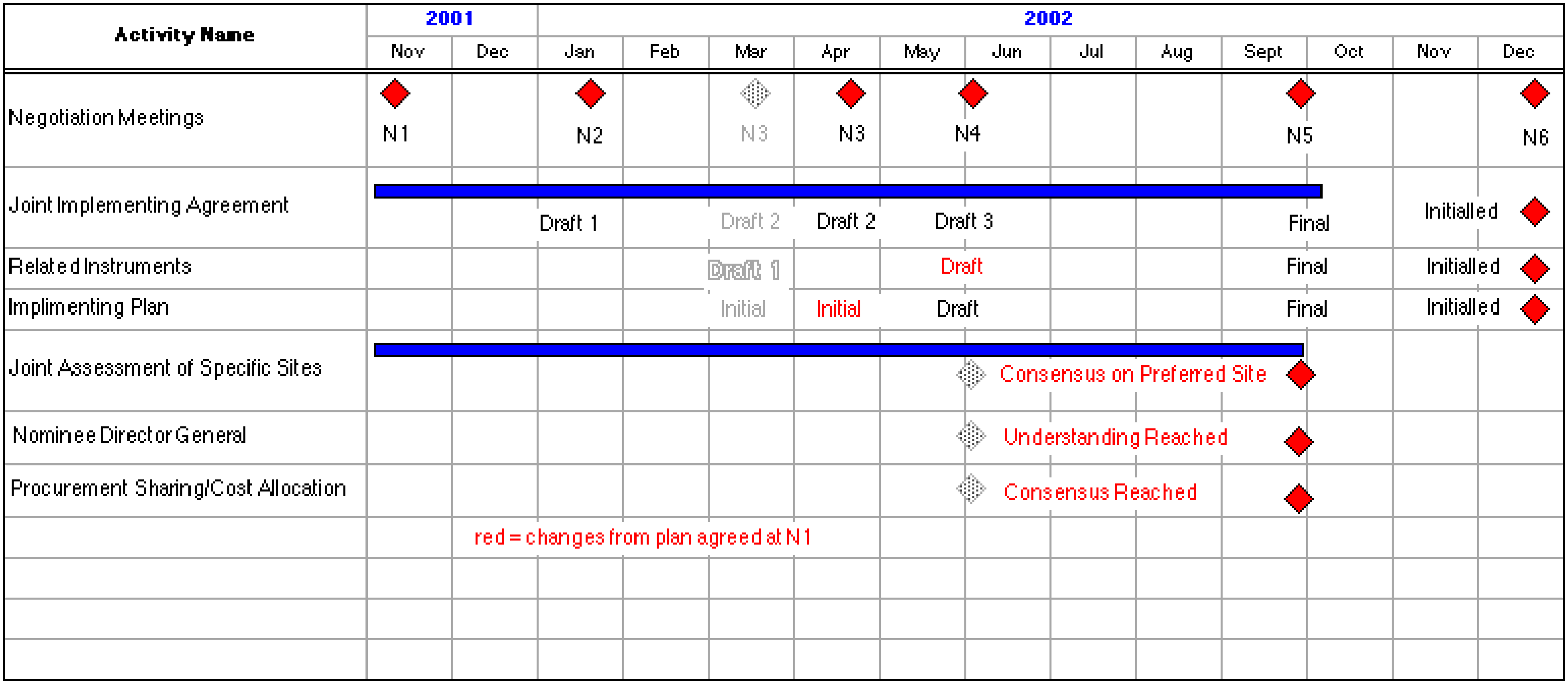
FIRE Could Explore Advanced Tokamak Regimes Close to ARIES-AT Parameters



The U.S. FESAC Dual Path Strategy

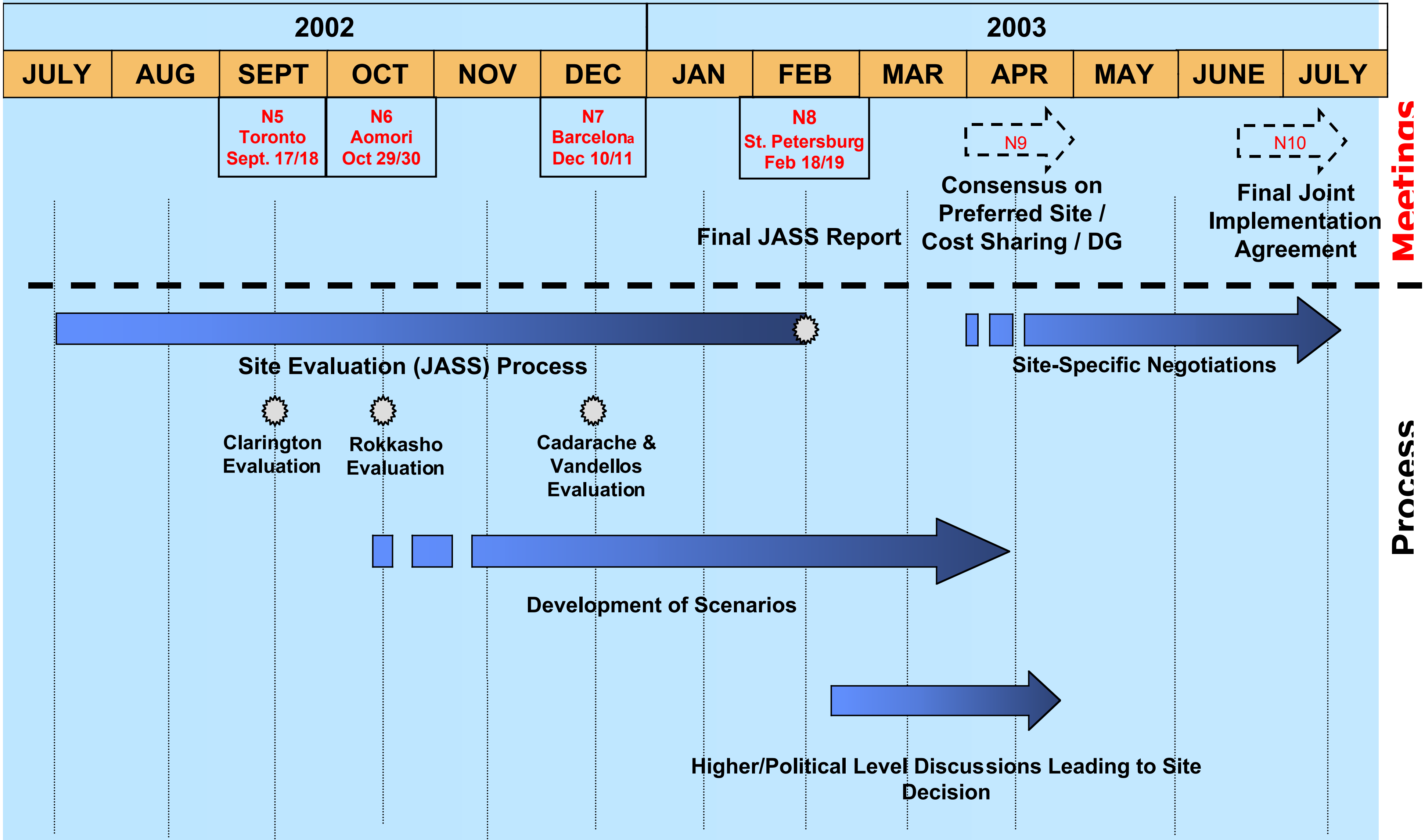


ITER Negotiation Schedule, September 18, 2002



ITER Schedule at the time of FESAC Recommendations on Burning Plasma Strategy

Timetable for Consensus on Site Preference and the JIA for Signature



Schedule agreed at St Petersburg meeting, February 2003