APEX
PHYSICS CONNECTION, TECHNOLOGY PROGRESS, LIMITATIONS AND NEW APPROACH

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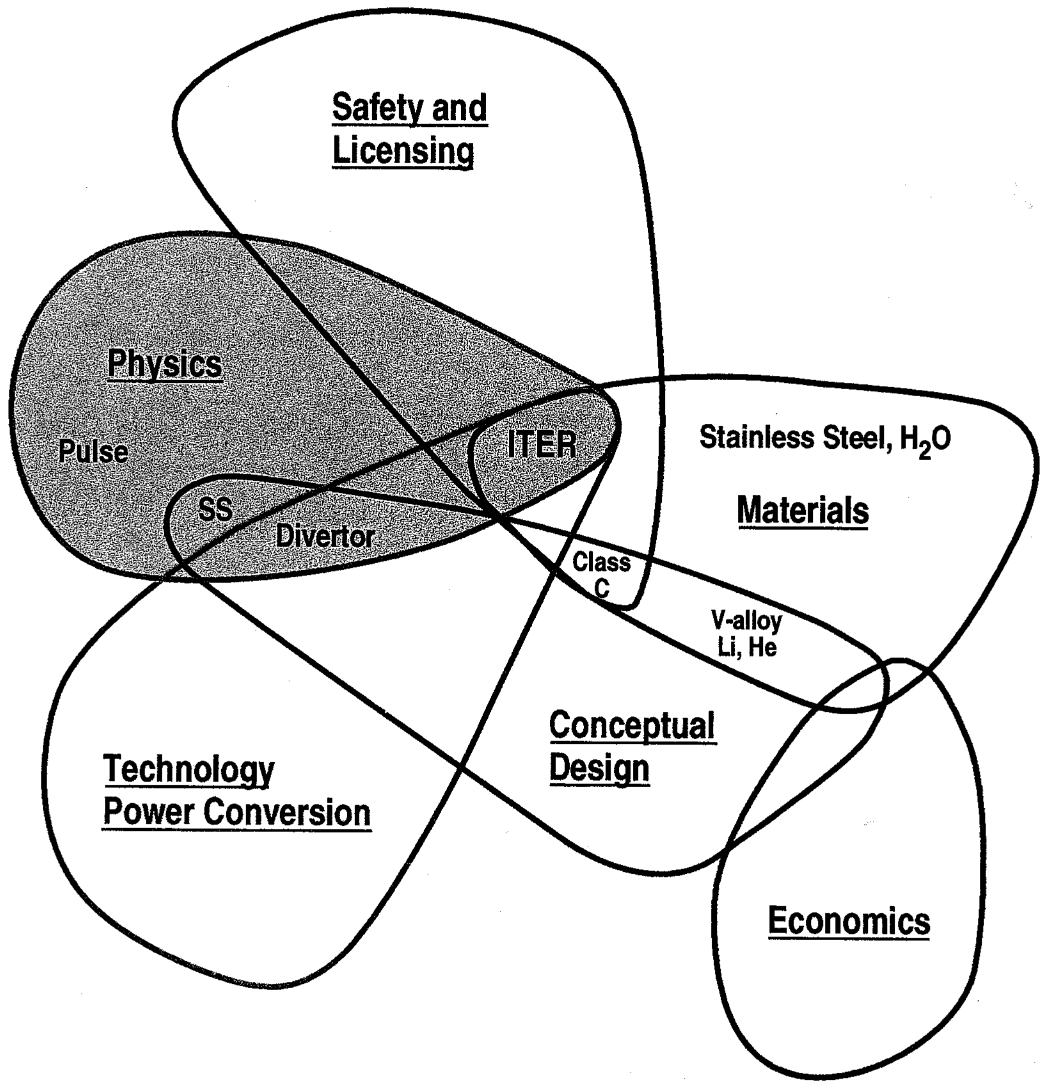
GENERAL ATOMICS

OUTLINE

- Tokamak nuclear power system and advanced tokamak physics studies are not in congruent
- ITER design confirms the difficulties
- Advances in physics and technology are in progress and should be recognized
- Potential attitude change suggested
- Recommendations to APEX

1997 U.S. FUSION PROGRAM



TOKAMAK DESIGN DIFFICULTIES

- Disruption effects dominate FW/B structural design
- Disruption can deliver $>10^5$ MW/m^2 to PFCs
- Chamber damaged from runaway (>300 MeV) electrons
- C & Be erosion limits ITER-PFC lifetime
- Maintenance approach is a key to machine availability
- Transient events (e.g. ELMs) contribute to intermittent heat fluxes
- Large machine SC-magnet is very costly

SOME RELEVANT PHYSICS ADVANCES

- Core radiation: use of Kr or Xe, it may be possible to trade off first wall and divertor heat flux
- High-Z first wall results (Mo and W)
- Mantle radiation research in progress: RI–mode
- Detached plasma and radiative divertor research in progress
- Disruption mitigation with impurity pellet injection in progress
- Low aspect ratio concept performance could be limited by technology and not by physics

EXAMPLE OF SIGNIFICANT TECHNOLOGY ADVANCES SINCE BCSS

- W plasma spray is a credible technology
- Large CaO MHD insulation tube tested
- Brazing of dissimilar materials is credible
- ITER has made significant progress in remote handling, SC coil design and fabrication, divertor design, handling of disruption, shield design and analysis, test module design, . . . etc.
- Understanding on PMI
- ALPS program planning in progress

PROGRESS IN He APPLICATION

- High pressure helium improves CCGT gross η_{th} (~45% at 650°C and 15 MPa)

- He removal of ϕ > 4.5 MW/m^2 with V-alloy tube demonstrated at 4 MPa

- 10 MW/m^2 can be removed at ~6 MPa

- Aluminized V-alloy shows no mechanical properties degradation in air to 500°C for 2500 h

- He/V/LM-FW/B shows capability of handling $\Gamma_n$ave > 8 MW/m^2, ϕ_{fw} ave > 2 MW/m^2

DESIGN LIMITATION EXAMPLES

Fundamental Issues

- FS-$T_{max} < 5\overset{5}{\cancel{0}}0^{\circ}C$
- SiC/SiC-K_{th} ~ 10 W/m•K at >1000°C, irradiated
- C, Be — high erosion rate
- C, Be — high T retention
- Solid sphere pac-K_{th} and contact resistance limited
- SC-magnet IB shielding

Critical Issues

- Li-self-cooled MHD insulation
- He-coolant reliability
- He/V-alloy compatibility
- W erosion due to arcing and melting due to disruption
- Irradiated alloy embrittlement

EVALUATION APPROACH

Traditional

- Physics parameters as design input
- Series development physics/ tech/materials/engr
- Fission Rx experience: design and materials
- HPD means divertor and high neutron wall loading
- An evolutionary process

New

- Iterate with physicists to work on plasma scenarios
- Parallel development physics/ tech/materials/engr.
- Utilize Nu + aerospace + electronics . . . experience
- HDP means plasma
- Add revolutionary process
- Attack critical issues

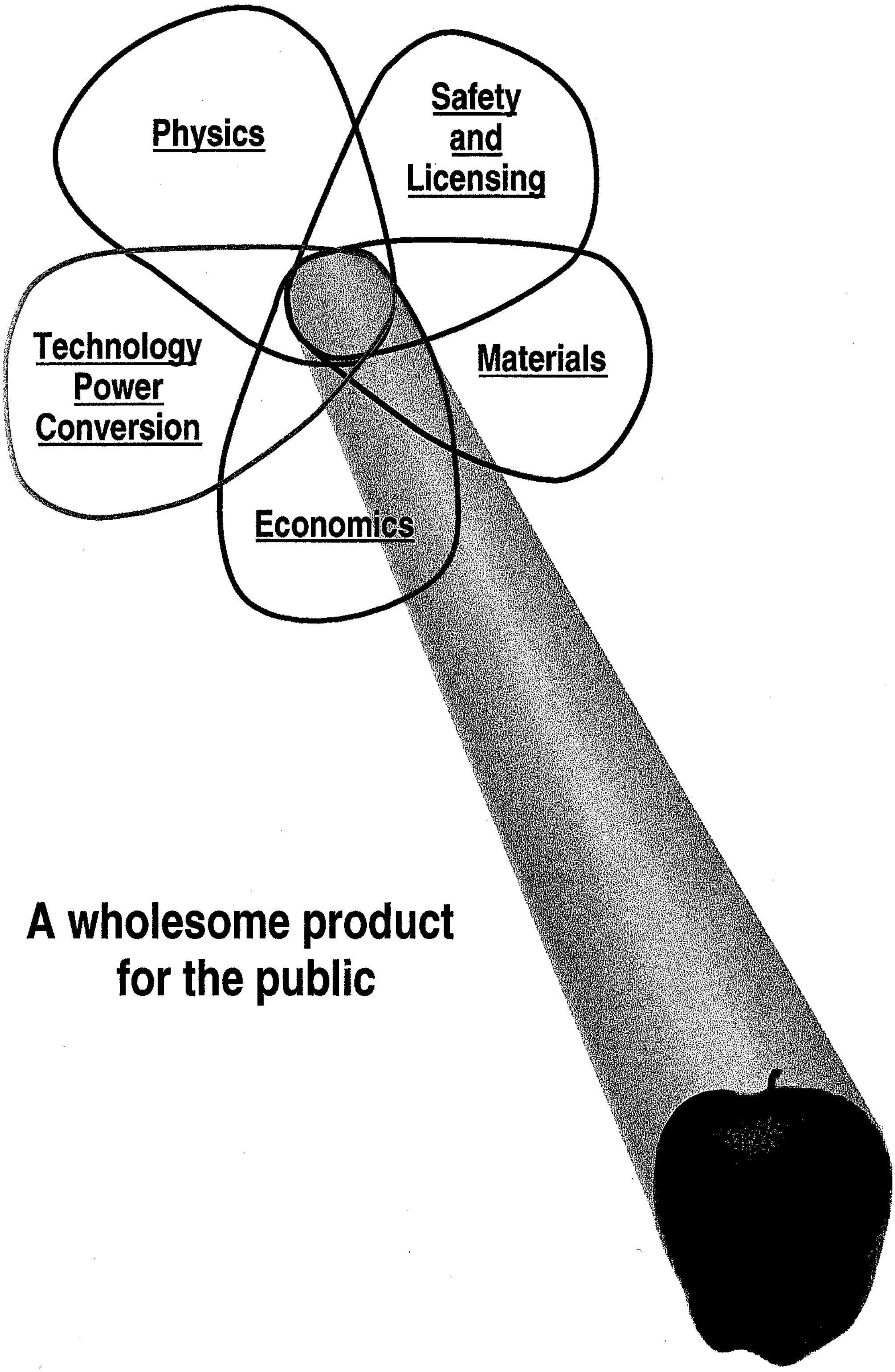
RECOMMENDATIONS TO APEX

- Initiate the HPD understanding from the plasma
- Iterate with physicists to define the appropriate plasma scenario for reactor operation
- Work with concept proponents on designs and R&D identification
- Perform detailed evaluations and R&Ds on high payoff critical issues
- Evolve the fusion program towards parallel development on physics/ technology/materials/engineering
- Be alert on power conversion innovation including direct conversion
- Increase engineering and fabrication knowledge base by adding other industrial practices: e.g., aerospace, electronics, and advanced materials, . . ., etc.
- Enhance communication through workshops, reviews, and actively solicit inputs from other disciplines

CONCLUSIONS

- There is a clear disconnect between tokamak physics development and tokamak power plant design
- Problems are recognized, some solutions are proposed but not well coordinated
- High payoff design critical issues should be addressed, fundamental design issues should be recognized
- An outward looking approach to other industries is needed
- We are at the verge of the next level of understanding but close collaboration between physics/technology/materials and engineering is required for the APEX program . . . this is a significant challenge
- Working in concert with physics is the only way to bear fruit for the fusion power development for the next century

FUSION 21 CENTURY GOAL



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