ALPS Status and Plans

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Agenda

- Approach and key issues
- Recent highlights
- FY 2000 plans

R&D Effort

- Near Term
  - » Address feasibility issues
  - » Provide data needed for concept evaluations
  - » Laboratory scale experiments
  - » Perform tests in fusion plasma facilities (e.g.DiMES)
- Long Term
  - » Address performance issues
  - » Perform larger scale, integrated tests
  - » Initiate concept exploration tests
  - » Comprehensive safety analysis

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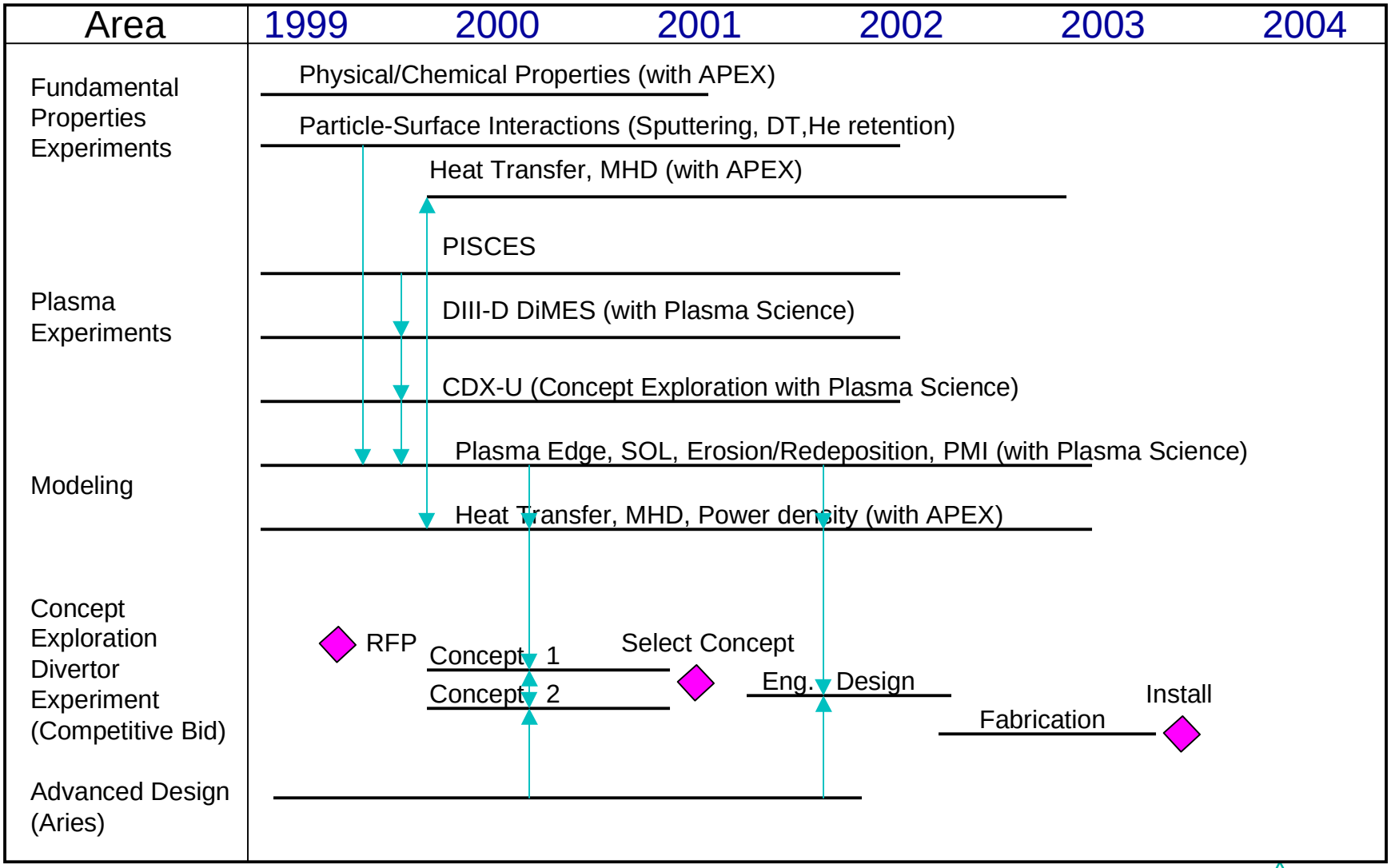
ALPS Schedule



Key ° Technical Issues for ALPS

- Effect of liquid surfaces on plasma edge and core performance
  - » Vaporization
  - » Sputtering
  - » Ionization
  - » Transport
  - » Scrape-off barrier efficiency
  - » Edge plasma optimization, e.g. aux. Heating
- Transient/disruption events

Key Issues (cont.)

- Achieving high power density
  - Temperature limits
  - Fluid flow behavior (e.g. MHD)
  - Integration with BOP
  - Flow length
- DT/He trapping and release from surfaces
  - Tritium inventory, transport, and control
  - Tritium purification and fuelling system needs
  - Pumping and exhaust
  - Chemistry Control

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Effect of liquid surfaces on plasma edge and core performance

- Candidate liquids could trap DT/He particles striking the surface.
- Other gas impurities may also be gettered.
- Sputtering and vaporization of the liquid surface will release particles into the SOL.
- The likely outcome is a modification of the plasma edge conditions.
- Both modeling and experimental programs are underway to address these effects.

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Modeling of Plasma Edge and Erosion / Redeposition

- UEDGE and WBC codes have been used to model an ITER-like configuration.
- Lithium is the divertor material, and it is expected to trap DT particles.
- UEDGE results predict a high edge temperature, ~220 eV, low particle density,~$1x10^{19}$ m^{-3} regime.
- WBC results predict > 99% redeposition of sputtered Li particles.

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Summary of WBC Codes Predictions

T_e(eV)/N_e(10^{19} m^{-3})

Parameter	200/1.5
Mean free path for sputtered atom ionization (perpendicular to surface)	1.8 cm
Average charge state	1.8
Transit time (Average)	52 μs
Elevation angle (Average)	59 Degrees
Energy (Average)	~1 KeV
Poloidal distance from launch point (Standard Deviation)	7 cm
Redeposition fraction (for 20 cm near –surface cutoff)	0.99

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PMI Experimental Studies

- Several institutions have ongoing programs to investigate liquid surfaces.
  - » Sandia National Laboratory
  - » University of California (San Diego)
  - » University of Illinois (Urbana-Champaign)
  - » General Atomic.
- Materials being studied include Li, SnLi, and Ga, with Flibe work planned for FY 2000

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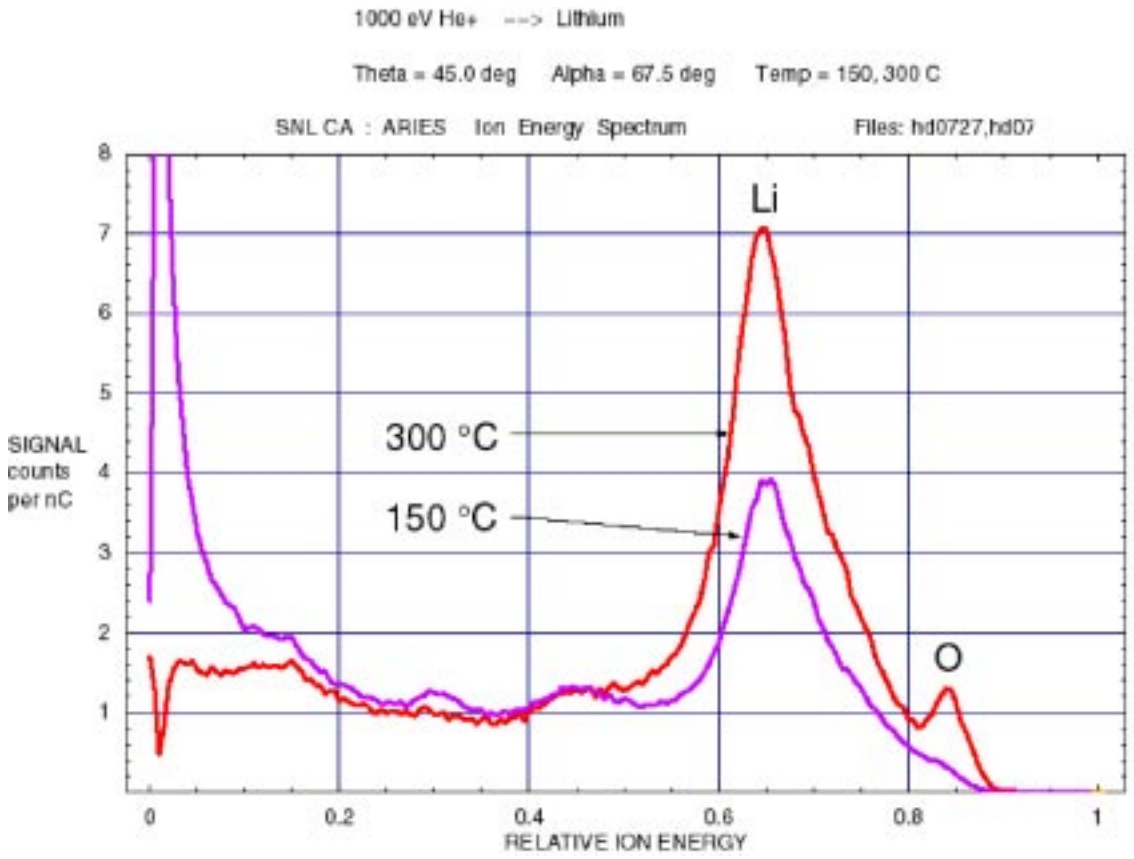
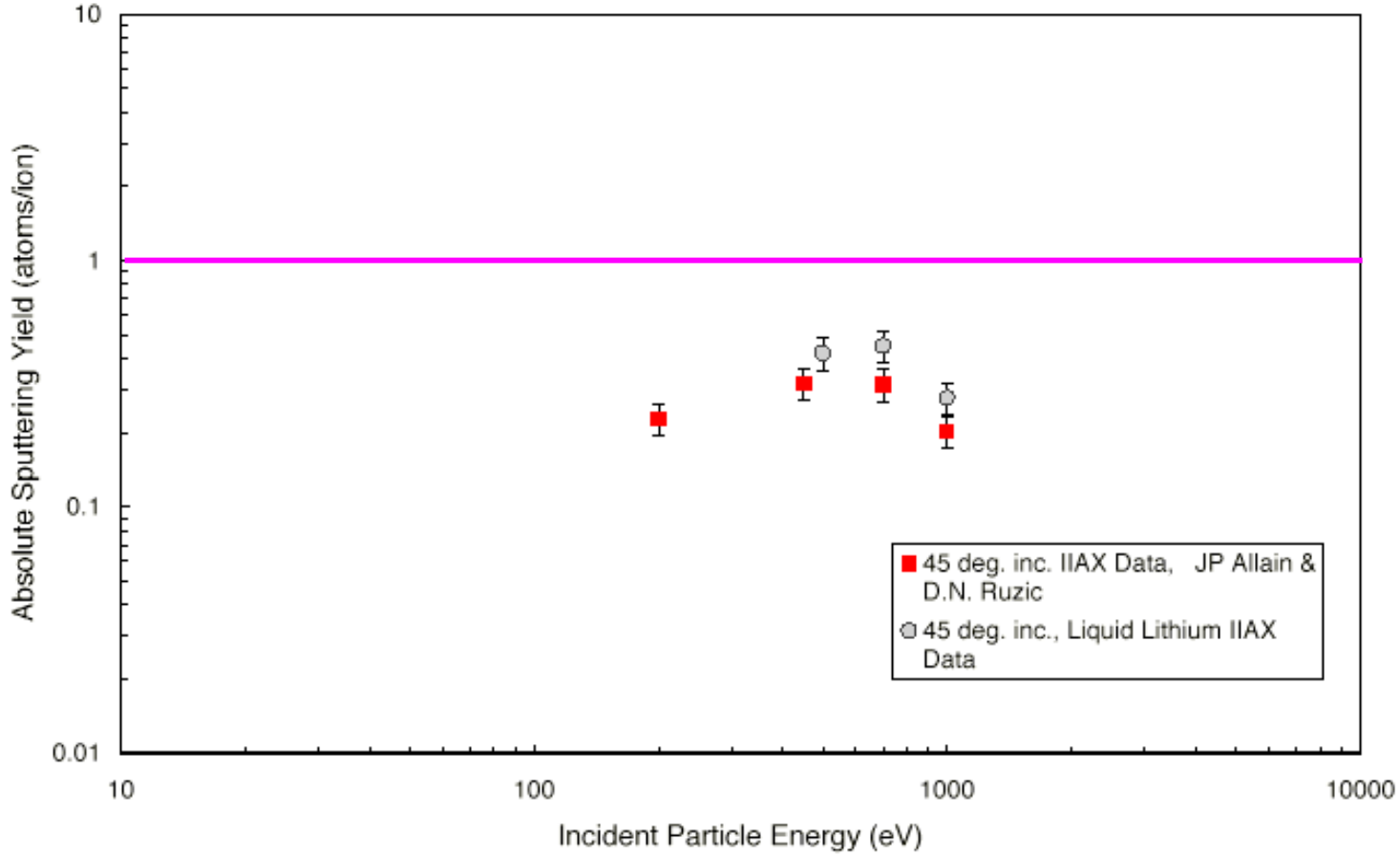
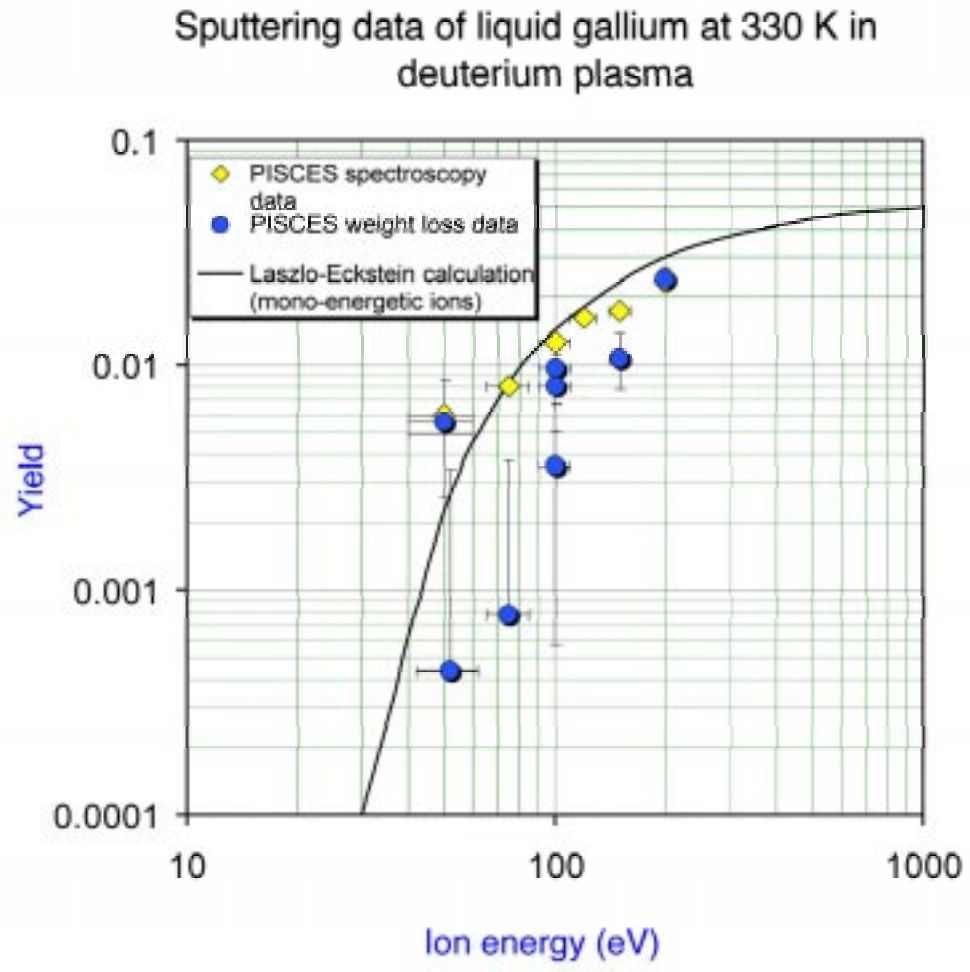
Melting of Li Results in Segregation of Oxygen to the Surface



Li+ on D-saturated Solid and Liquid Lithium

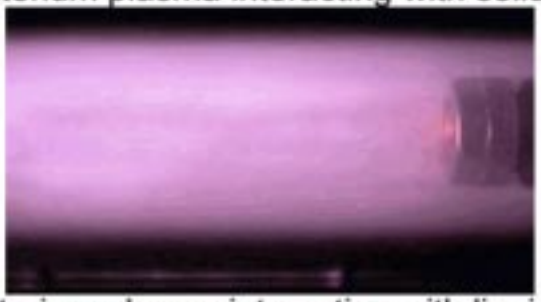


Sputtering coefficient of liquid gallium compared with model predictions.



Liquid Li Interaction with Plasma in PISCES

Deuterium plasma interacting with solid lithium



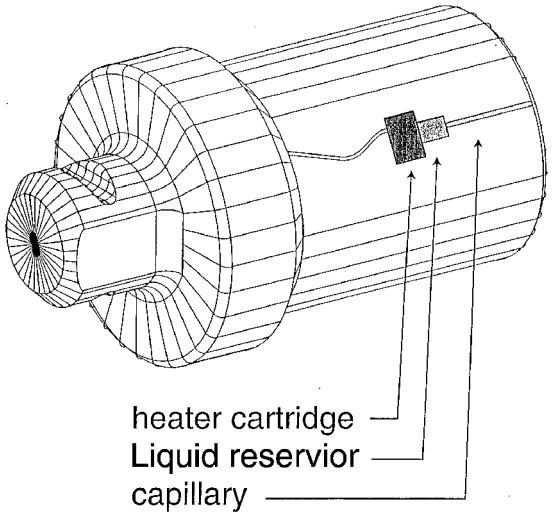
Deuterium plasma interacting with liquid lithium

Filtered interaction with liquid lithium

DiMES Li Experiment

- A 0.5mm thick lithium sample was recently exposed with the DiMEs system on the DIII-D lower divertor.
- Data was obtained during several plasma shots with varied plasma conditions.
- Detailed plasma and spectroscopic data will be distributed to DiMES collaborators for analysis. The sample will also be shipped to SNL for material analysis.

DiMES Tests



Transient / disruption events

- Vapor cloud formation results in less than 10% of the original incident power striking the surface because of the shielding effects.
- Disruptions may lead to splattering of liquid surface and removal of the vapor cloud.
- Enhanced sputtering is possible for liquid surfaces
  - » Bubble formation and bursting
- Modeling work is ongoing.

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Review of the status of work for MHD flow on a plate, jets, and droplets

- There are several uncertainties that are potential concerns.
  - » Stability of the film
  - » Uniformity of film height owing to inertia
  - » 3-D effects
  - » Inclination of the field
  - » Plasma wind
- It is recommended that the initial focus be on liquid jets for divertor applications.

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DT / He trapping and release from surfaces

- Integrated into PMI experimental studies.
- Trapping probability depends on chemical solubility along with the kinetics of particle diffusion and release.
- He pumping may occur if the residence time is sufficiently high.
- Available information is insufficient to adequately evaluate possible He pumping capability.

FY 2000 Task Areas

- Effect of liquid surfaces on plasma edge and core performance
- Transient/disruption events
- Achieving high power density
- DT/He trapping and release from surfaces
- Support for CDX-U
- Divertor design

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Effect of liquid surfaces on plasma edge and core performance ($1250 K)

- Analysis of plasma edge and E/R for candidate liquids (ANL,LLNL,UIUC)
  - Li
  - SnLi
  - Flibe
- 3D sheath code development/analysis of evaporating liquids (ANL,IPP-Garching)
- WBC code and related code modeling/analysis of DiMES experiments (ANL,GA, et al.)

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Effect of liquid surfaces on plasma edge and core performance

- Provide 2-D hydrogen edge-plasma profiles from ARIES for use in near-surface test-particle codes and core systems codes.(LLNL)
- Determine first-wall temperature limits based on impurity influx in ARIES for Flibe and Lithium with optimal assumptions. (LLNL)
- Assessment of advantages of different device geometries and plasma-engineering intervention techniques such as auxiliary heating for impurity wall influx. (LLNL)

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Effect of liquid surfaces on plasma edge and core performance

- Surface composition studies on candidate liquids (SNL)
- Sputtering studies on candidate liquids (UIUC)
- Preparation of DiMES experiment (SNL, GA)
- Conduct DiMES experiment (GA)
- Analysis/post test examinations of DiMES experiment (SNL, GA, ANL)
- Plasma interaction studies with candidate liquids (UCSD)

Transient / disruption events (ANL-$200k)

- Analysis of disruption behavior on liquid divertors
- Develop fundamental models of PMI during all transient events (disruptions, ELMS, VDE, runaway electrons)
- Support APEX analysis of first wall

Achieving high power density ($400 k)

- Prepare and conduct high heat flux test with liquid metal in EBTS (SNL, ANL)
- Design and perform pre-test analysis of free surface MHD test (ANL, SNL, FZK)
- Design common systems for liquid metal test loops (SNL,ANL)

DT / He trapping and release from surfaces ($200 k)

- Develop models and analysis for helium and DT particle pumping for liquid surfaces (ANL)
- Design and conduct(?) experiment to measure kinetics of He/DT interactions with liquid surface (SNL,UCSD, UIUC, ANL)

Support for CDX-U ($550 k)

- Design and fabricate point limiter and toroidal limiter for CDX-U experiments (UCSD, SNL, ANL, et al.)
- Provide input to CDX planning and review process
- Conduct modeling/analysis of CDX-U plasma edge and PMI.

Divertor Design ($260 k)

- Conduct conceptual design of divertor for AIRES-AT (ANL, SNL, et al.)
- Perform MHD analysis of liquid jets
- Assist with APEX divertor integration task

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