Update of IFE Target Fabrication, Injection, and Tracking

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GENERAL ATOMICS

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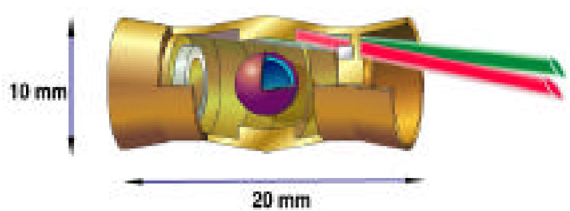
Target fabrication, injection, and tracking issues are being addressed in an integrated fashion

__Target fabrication critical issues__

1) Ability to fabricate target materials
2) Ability to fabricate them economically
3) Ability to fabricate, assemble, fill and layer at required rates

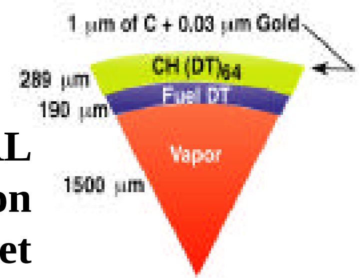
__Target injection critical issues__

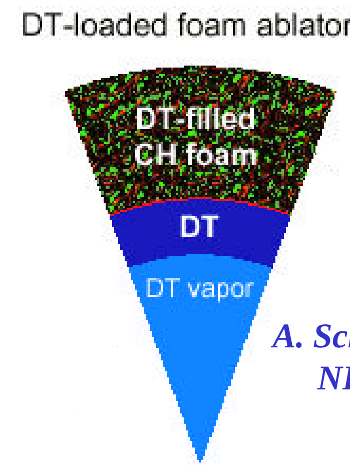
4) Withstand acceleration during injection
5) Survive thermal environment
6) Accuracy and repeatability, tracking



LLNL Close-Coupled HI Target

NRL Radiation Preheat Target





A. Schmitt, NRL

…. Presentation will briefly address the work being done for each issue

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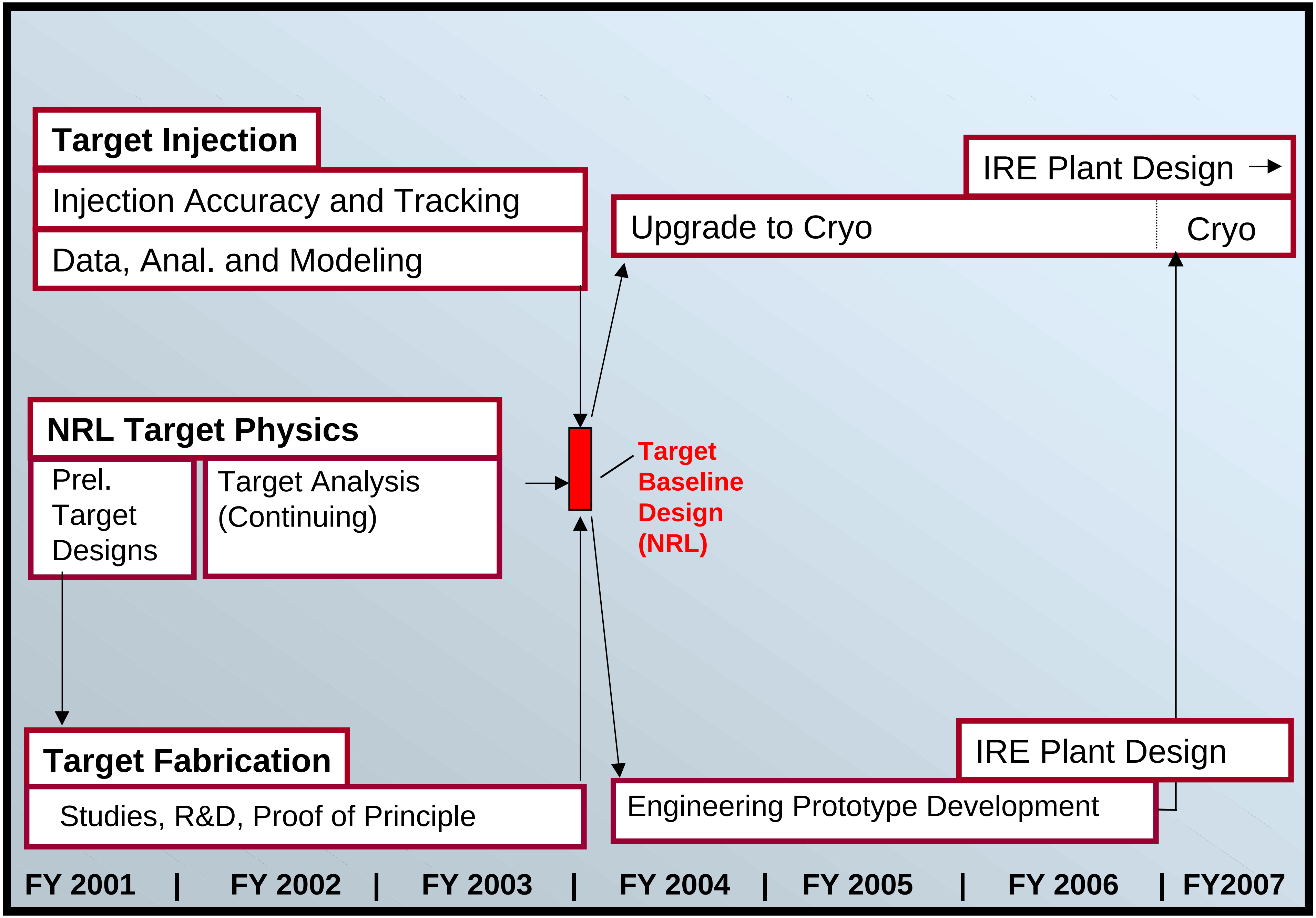
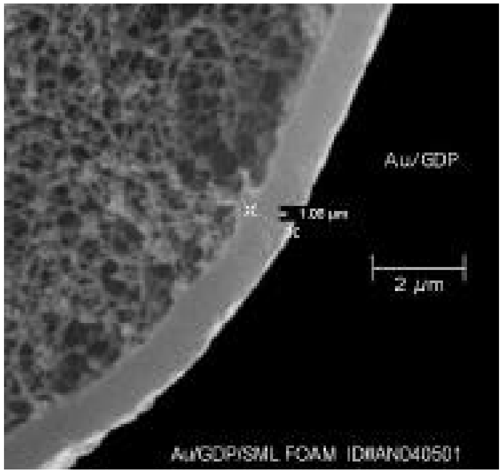
Simplified Target Fab/Injection 5-Year Plan



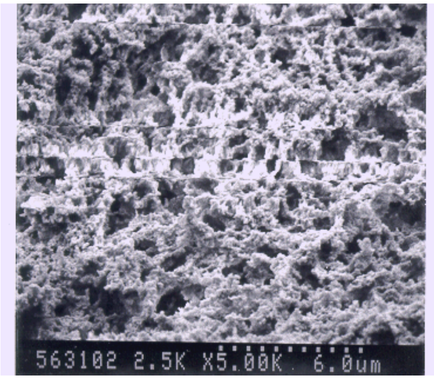
1) Ability to fabricate target materials

- Leveraging ICF fabrication experience
- Indirect drive targets
  - LANL is studying synthesis of metal doped organic foams
- Direct drive targets
  - Schafer is developing DVB foam shells and seal coats
  - GA is developing characterization
    - Technical planning meeting at GA 2/21/01 (GA/Schafer/LANL)
  - GA is depositing high-Z overcoat

Trimethylolpropane trimethacrylate foam shell with ~1 μm hydroxyethylcellulose seal coat plus GDP, with ~300 Angstroms of gold



10 mg/cc DVB foam (from Diana Schroen-Carey)



…. Initial materials fabrication and evaluation programs for both direct and indirect drive IFE targets are underway.

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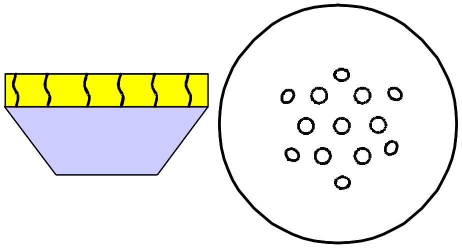
1) Ability to fabricate target materials - high-Z overcoat

- **Considerations:**
  - **Target design (Z, smooth, uniform)**
  - **Fabrication (ability to coat, cost)**
  - **Layering (IR or Joule heating)**
  - **Injection (stable, reflective)**
  - **ES&H (hazardous, mixed waste)**
- **Permeation through gold could be too slow**
- **Current focus**
  - **Coat 300 Angstrom gold & measure permeation**
  - **Evaluate alternatives/backups**



Gold deposited with columnar structure or pinholes can be permeable

Temp. (K)	Calculated Time to Fill Through High-Z Overcoat			
	Pd	Ta	V	Nb
300	4.4 hrs	50 days	1.3 yrs	6.6 yrs
373	1.4 hrs	10 days	60 days	0.44 yrs
Based on bulk metal properties only (no pinholes) and 0.047 atm overpressure				

…. Need to pursue baseline approach– but always have backups!

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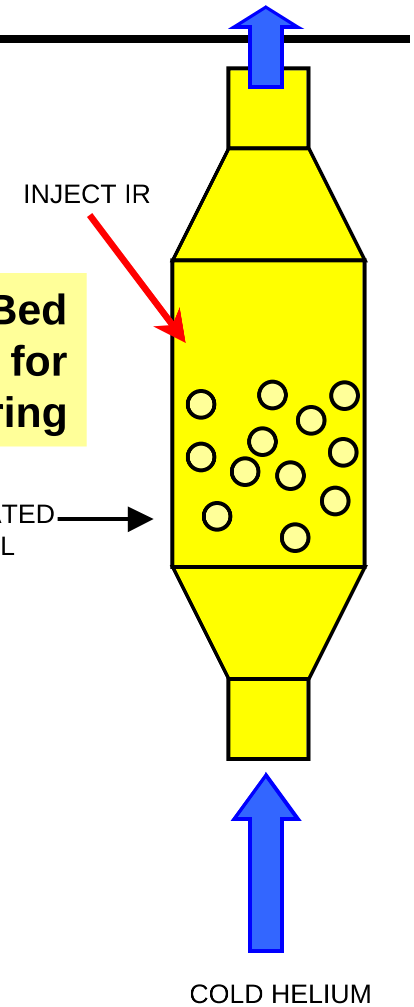
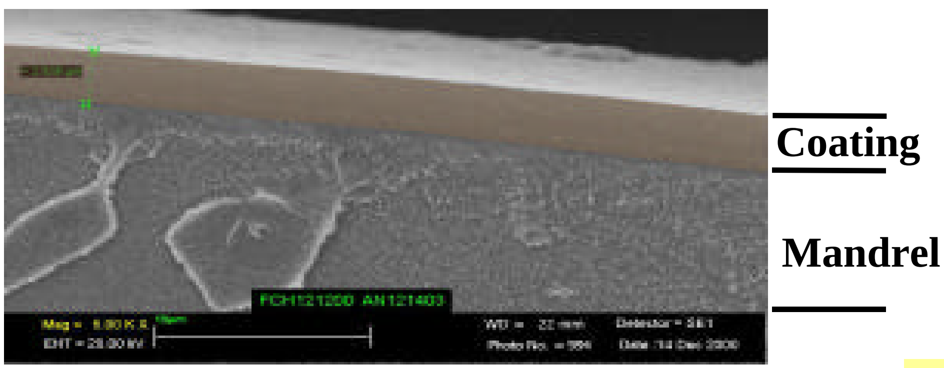
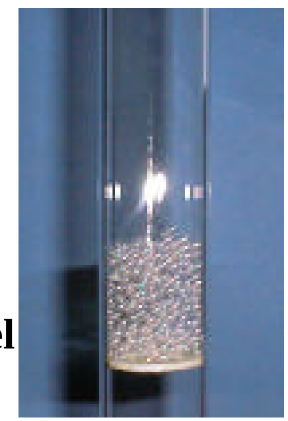
2) Ability to fabricate targets economically – utilizing industrial technologies

- Industrial technologies are being evaluated
- Fluidized bed is one mass-production technology
- Several runs for GDP coating have shown good results (GA)
- Can the concept be applied to cryogenic layering?
(GA, Schafer)

Fluidized Bed Concept for Layering







PAMS Mandrels in Fluidized Bed

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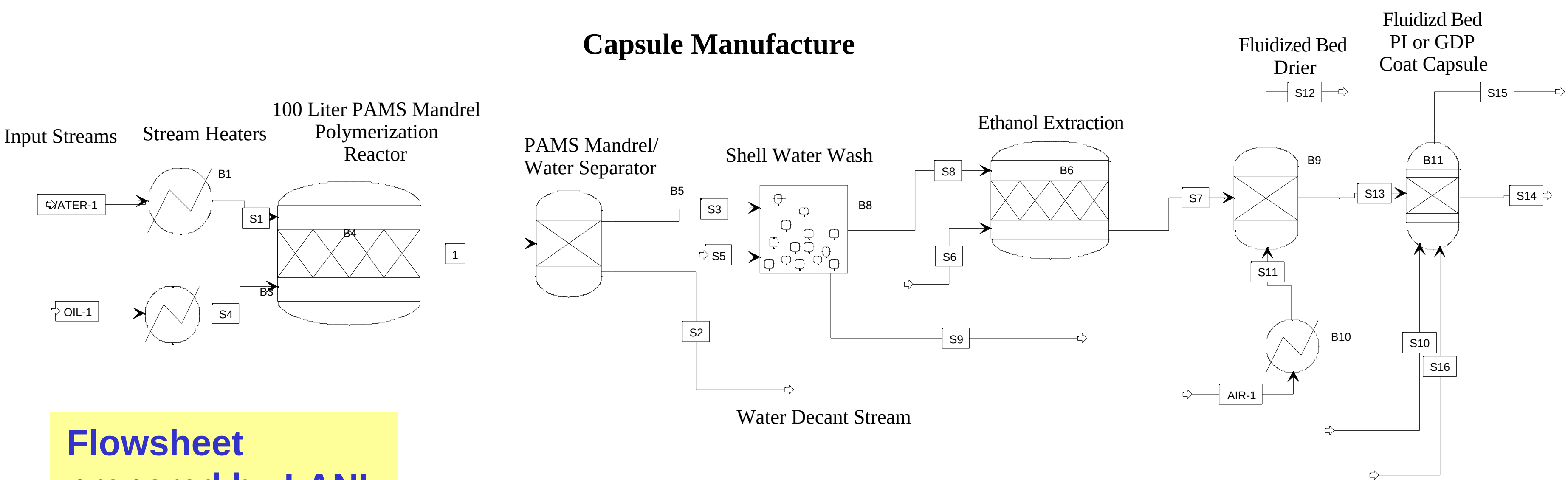
2) Ability to fabricate targets economically – chemical process modeling and cost estimating



Flowsheet prepared by LANL

…. Scaleup of existing bench scale processes will be evaluated using chemical plant design software (Aspen Plus)

…. Workshop on target fabrication facility equipment and cost estimates being planned (GA, LANL, LLNL, UCSD, …)

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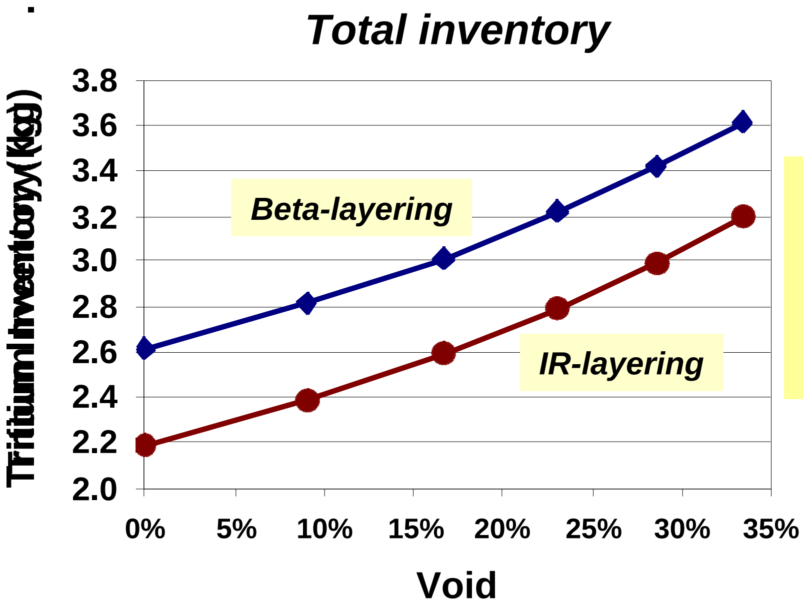
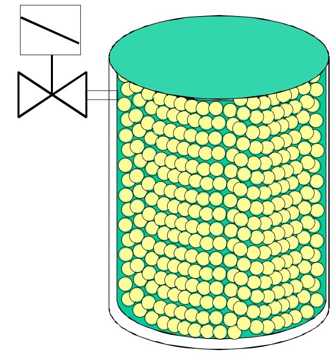
3) Ability to fabricate, assemble, fill, and layer at required rates – high volume filling

- **Permeation filling is demonstrated technology from ICF**
  - **Void volume reduction (LANL)**

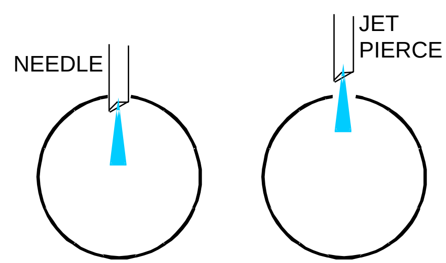


LANL Calculations of Total DT Inventory for Direct Drive Targets Filled at 340K



Large Batch Permeation

- **Alternative fill techniques (GA)**
  - **Direct injection of liquid DT**
  - **Fast filled liquid target**



Direct Injection

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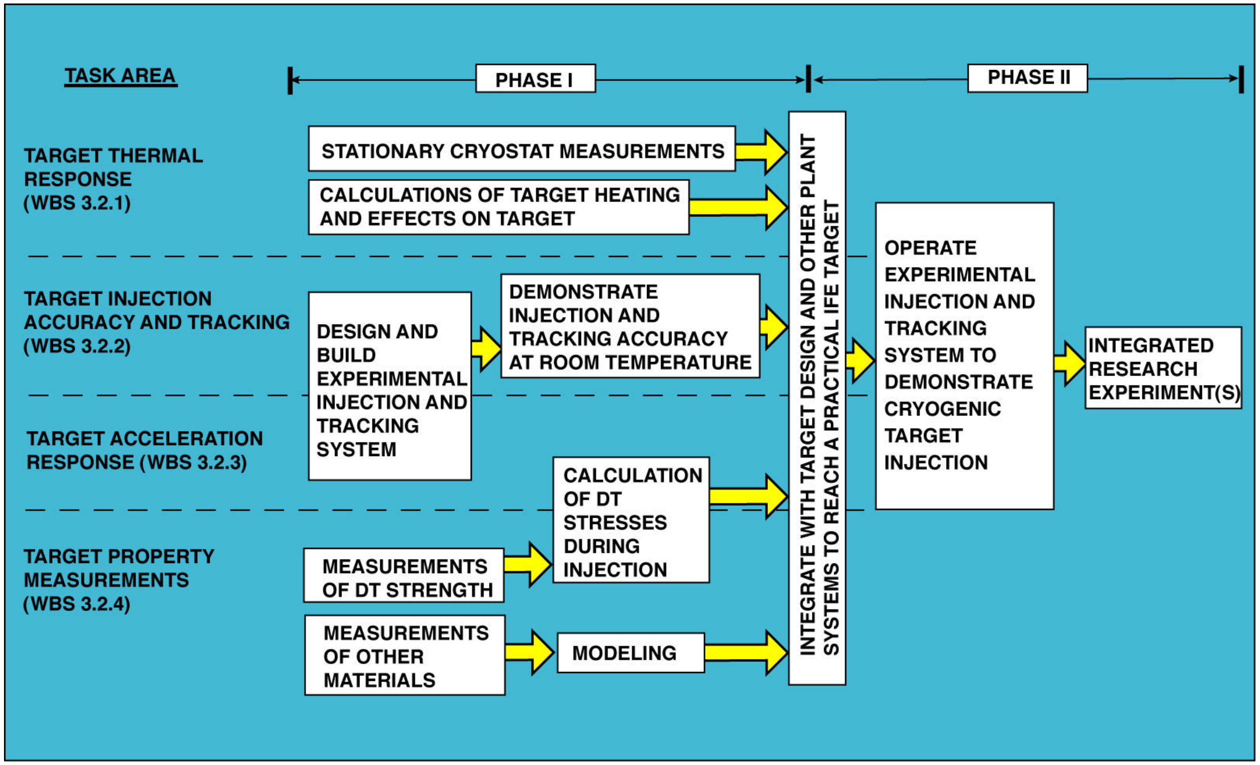
Target injection critical issues

- **Target injection is pursuing the Experimental Plan developed in FY99**

"Experimental Plan for IFE Target Injection & Tracking", GA-C23241 (Oct, 1999)



Program is a combination of

-analyses & modeling

-materials property meas.

-demonstrations

…. Ultimate goal is demonstration of injecting cryogenic targets into hot chamber

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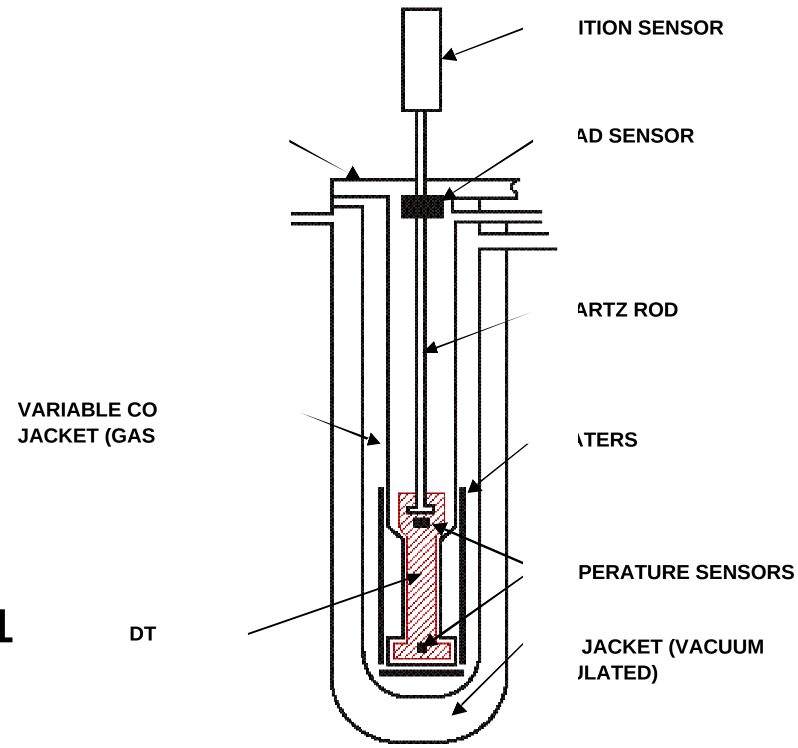
4) Withstand acceleration during injection – materials measurements are needed

- Have estimated DT can withstand 1000g acceleration at 18K
  - But based on hydrogen properties extrapolated in both isotope and in temperature
- Need to measure DT yield strength and modulus under representative conditions
  - Correct crystalline form
  - Function of temperature
  - Function of time ($^3H \rightarrow {}^3He + \beta$)
- Planning meeting at NRL February 7, 2001
  - GA, LANL, NRL, Schafer
  - Reviewed objectives & requirements
  - LANL is developing detailed measurement approach



Ref: Krupskii, I.N., Soviet J. Low Temp. Phy. 3, 453, 1977

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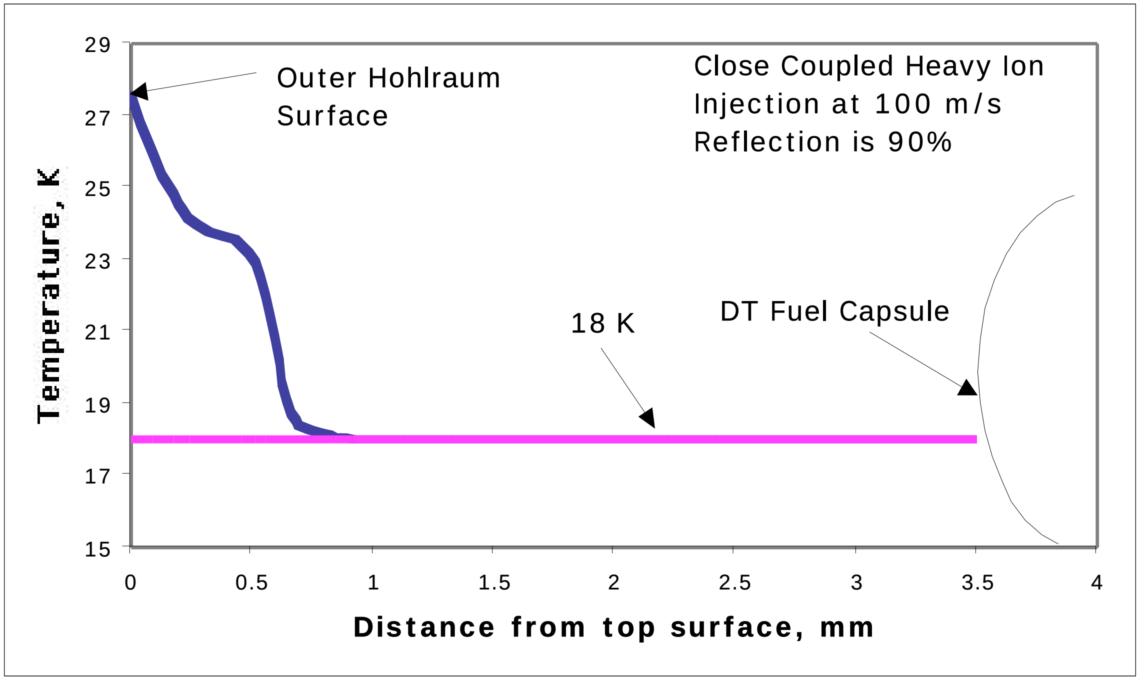
5) Survive the thermal environment – indirect drive target thermal calculations

- **ANSYS finite element model for indirect drive target**
  - **LLNL close coupled heavy ion driven target**
  - **30 ms acceleration with 300K surface temperature**
  - **30 ms coasting phase at 100 m/s**
  - **30 ms in-reactor phase assuming 930K and 90 reflectance**
- **Results show negligible DT heating during injection**



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5) Survive the thermal environment – direct drive target "success pathways"

Heating due to thermal radiation and from conduction/convection from the chamber gas

Target Survival

"Survival" Criteria?

Experimental Data

Reflectivity

Target Protection
-Sabot in chamber
-Injection Tube (UW)

Transmission

Criteria/concerns

High reflectivity
Permeation filling
Target physics

Wall damage
Waste
Materials Cost
Complexity

DT absorption
CH absorption
Target Physics

Next Presentation (Alexander)

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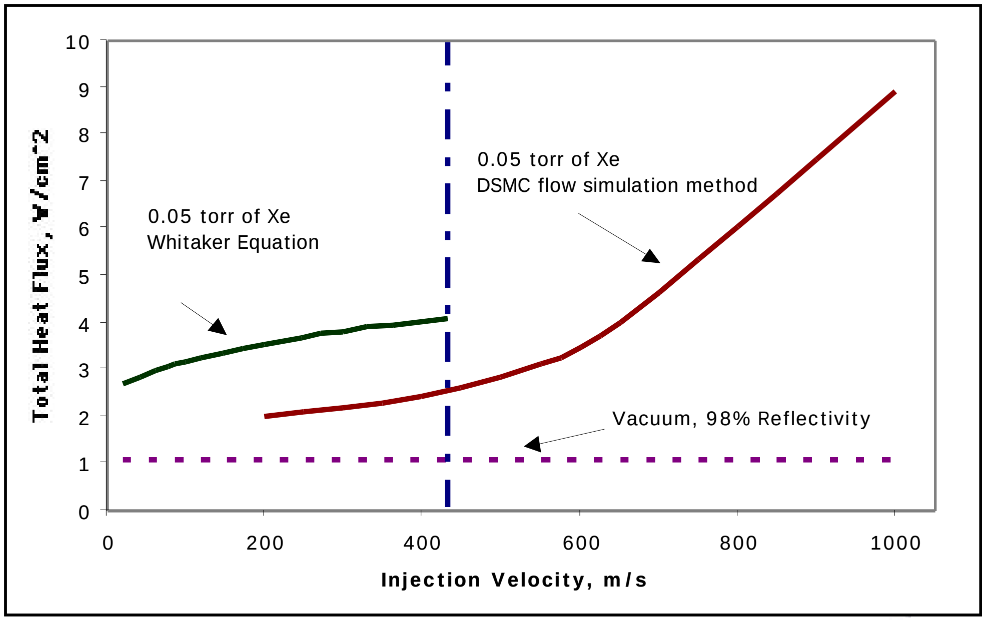

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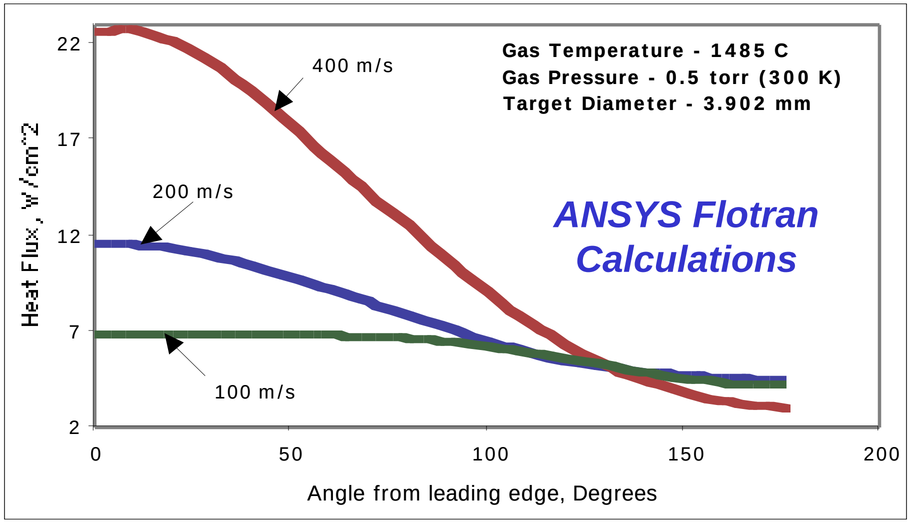
5) Survive the thermal environment – direct drive targets have a design window

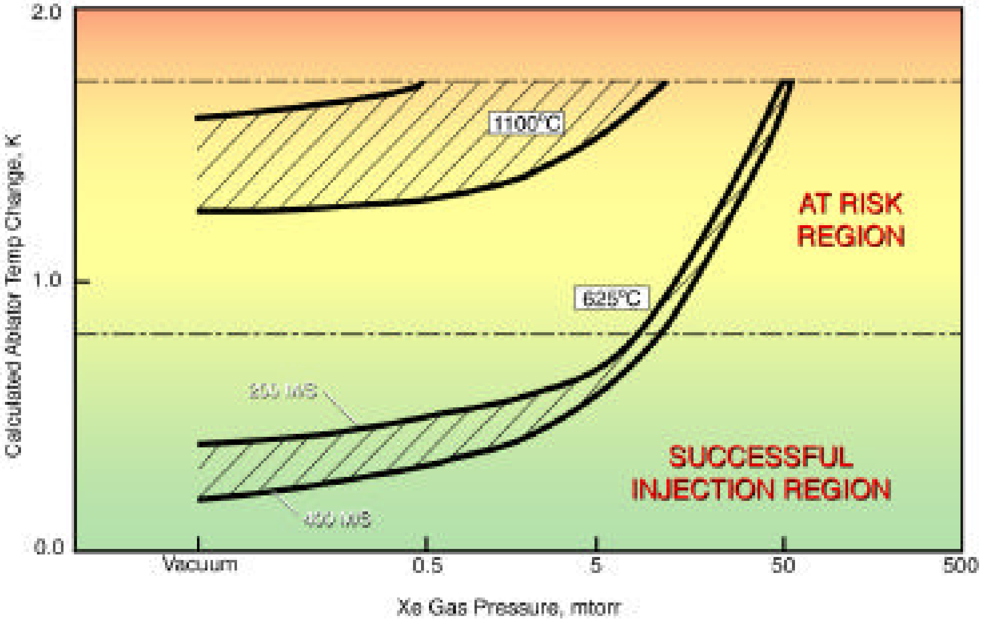
Excessive heating

Asymmetric heating

- Lower first wall temperatures
- Lower gas pressures



Assumes 98% target surface reflectivity



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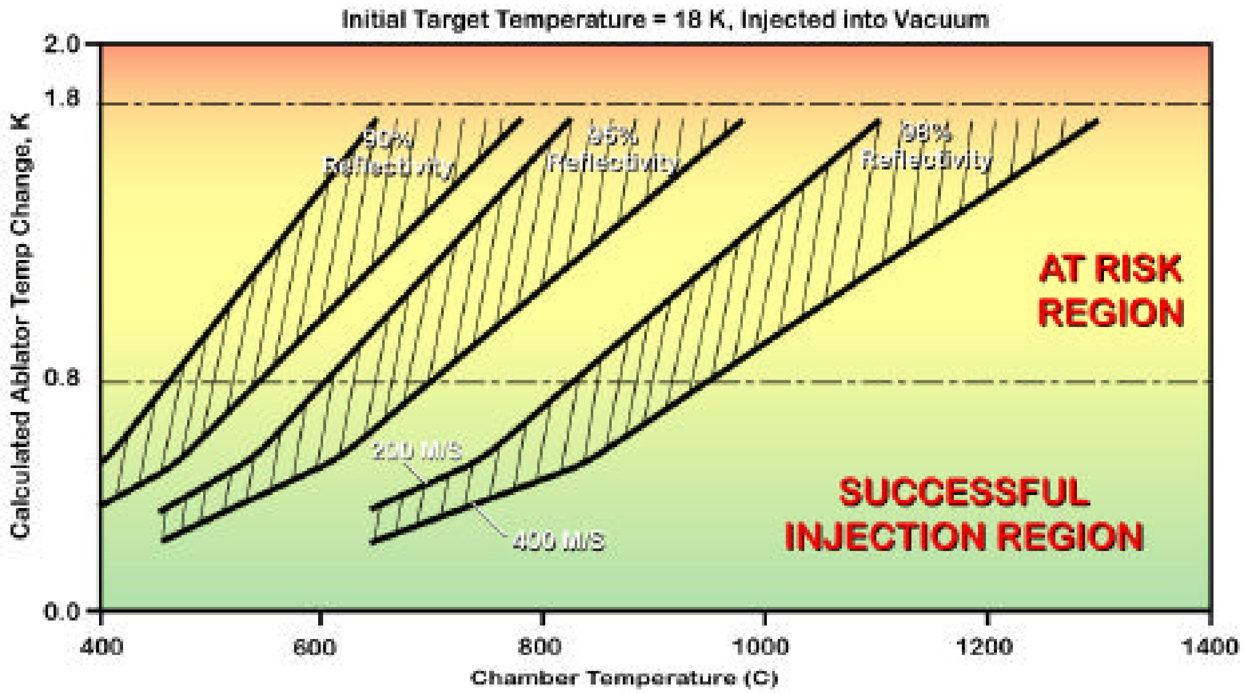
5) Survive the thermal environment – removing the chamber gas widens the "window"



Conclusions:

1) Analyses of target heating are well in-hand
2) Most important issues are:
   - Response of the DT to rapid heat flux
   - Ability to fabricate highly reflective targets
3) It's time for some data!

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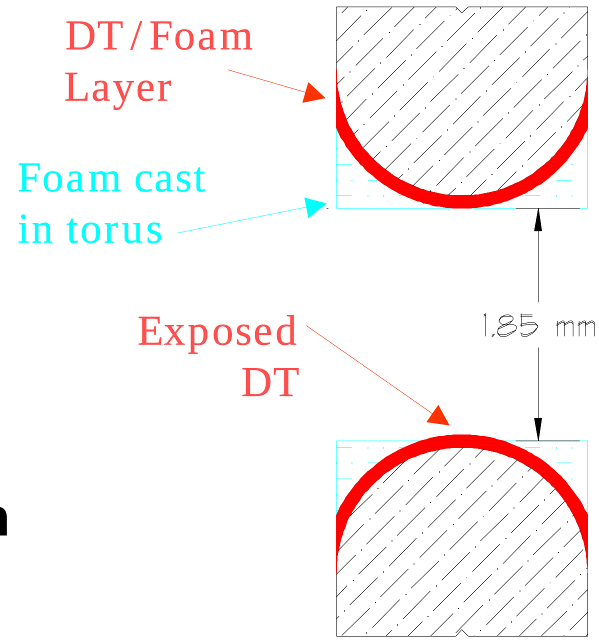
5) Survive the thermal environment – experiment on response of DT to a rapid heat flux

- Based on prior experiments done for ICF
  - Equipment available at LANL
- Cryogenic torus effectively turns the target "inside-out" – exposing the DT ice inner surface for viewing
- Experiment planning meeting at NRL on February 7, 2001 (LANL, GA, Schafer, NRL)
- Experimental equipment being evaluated/designed at LANL



Side view, cross-section of LANL cryogenic torus (windows not shown)

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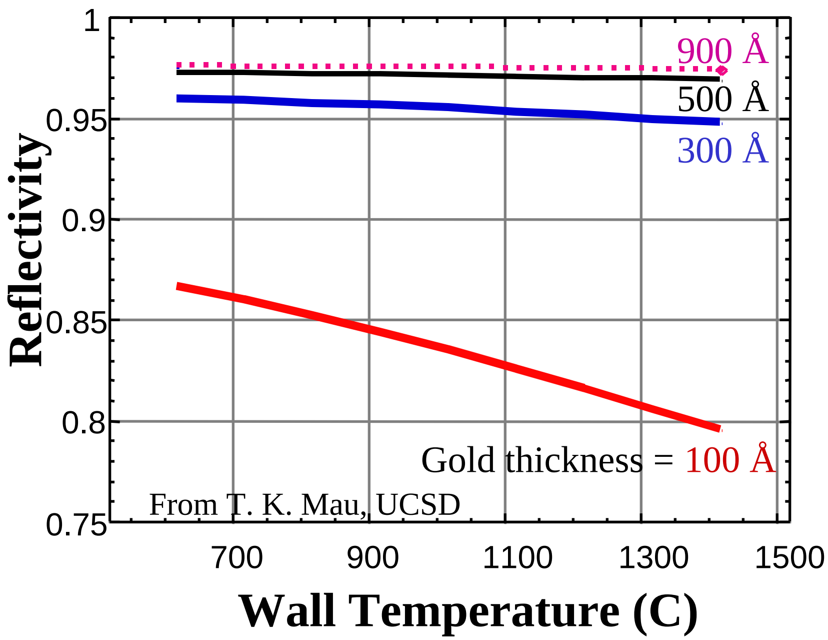
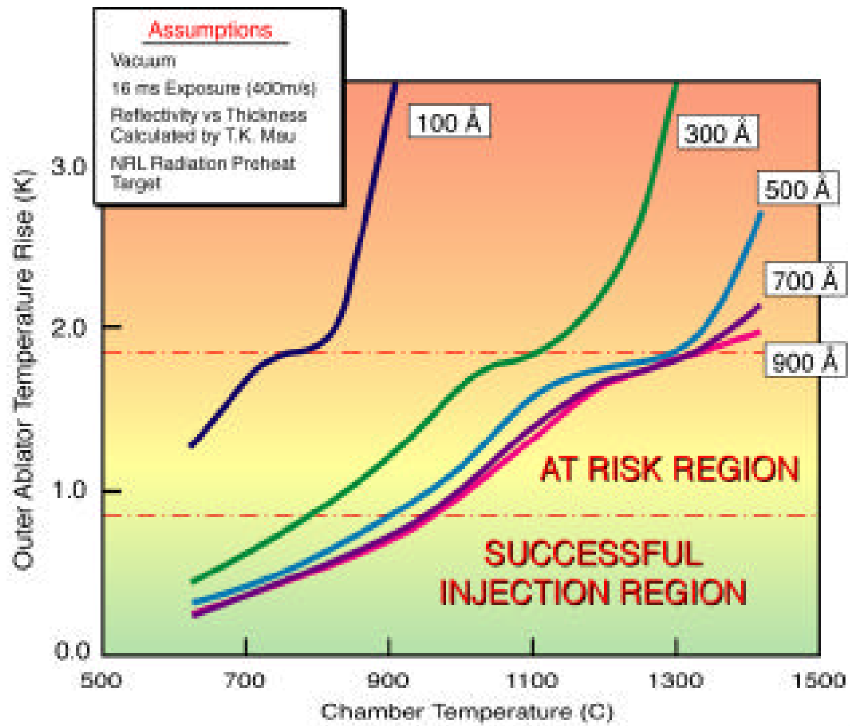
5) Survive the thermal environment – data on gold overcoating reflectivity

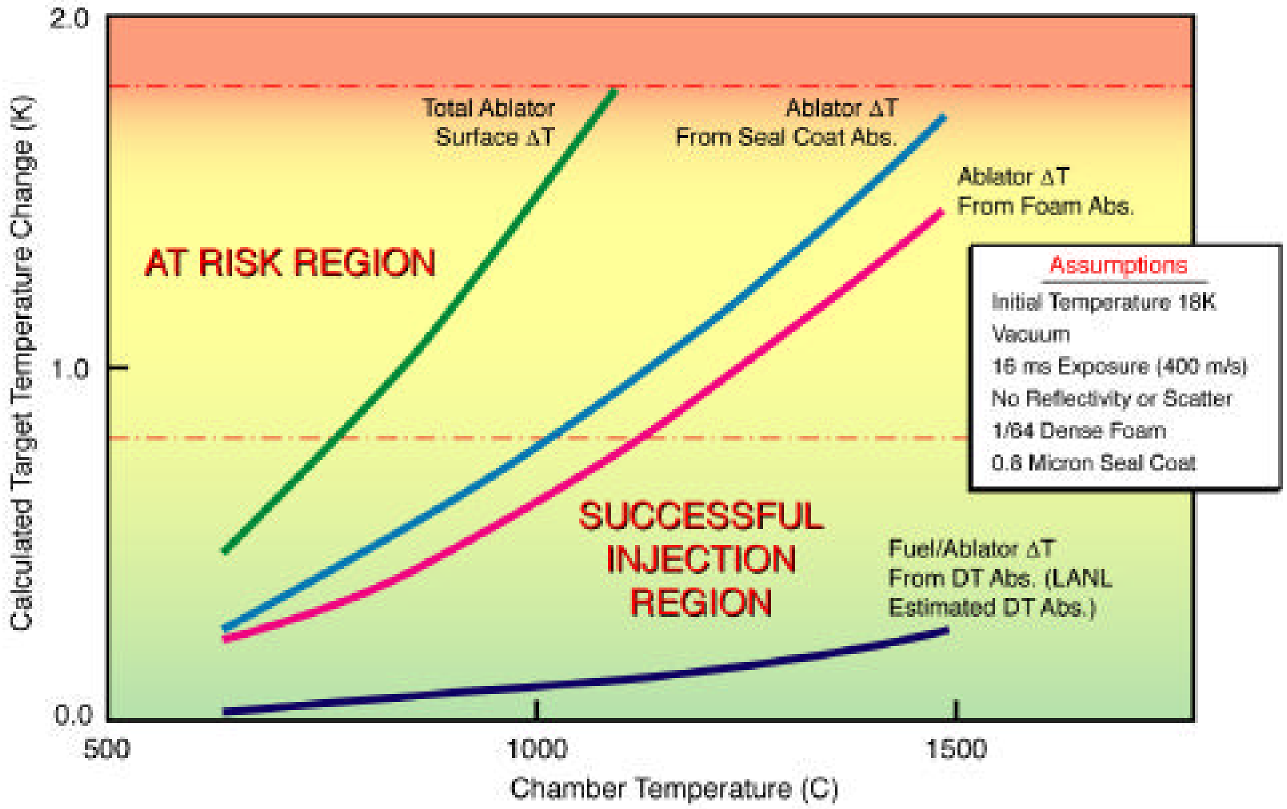
- Deposited gold layers on 1 μm of GDP (flats for now, spheres next)
- Measured optical properties with ellipsometry
- Calculated reflectivity as function of wavelength and angle of incidence
- Calculated overall reflectivity for a given blackbody spectrum
- Calculated the corresponding heat flux and compared to the 2-level criteria for survival





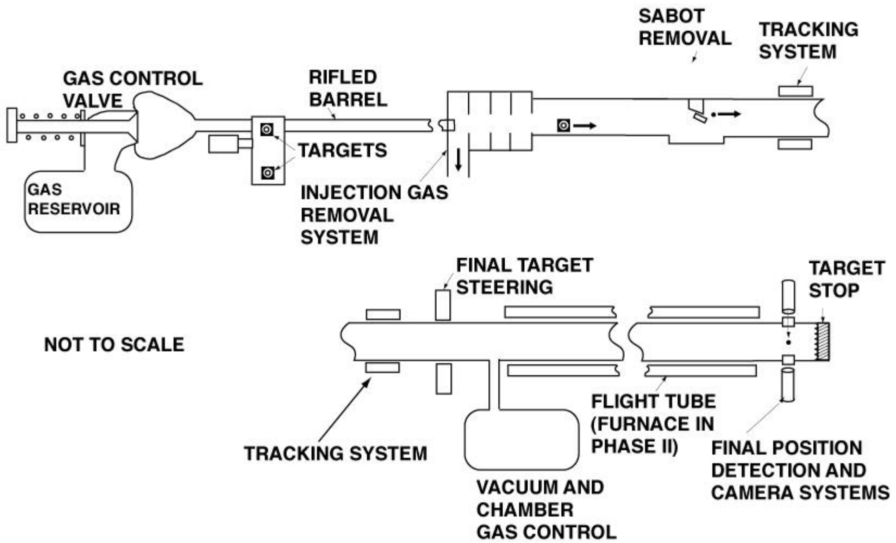
5) Survive the thermal environment – transmission may be a viable option

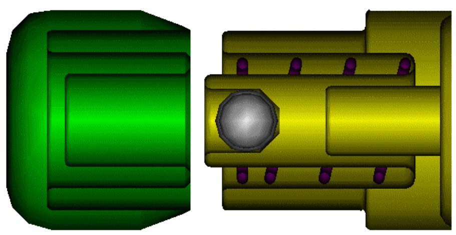
- Evaluated IR absorption bands for DT vs. blackbody radiation spectrum
- Calculated bulk heating of DT assuming normal incidence
- Results show low DT absorption



6) Accuracy and repeatability, tracking - experimental target injection and tracking system

- Strategy and approach
  - Acquire proof-of-principle <u>data</u> on target injection as soon as possible (RT first, then cryo)
  - Provide a facility to aid in developing practical, survivable targets
  - Develop and demonstrate injection and tracking technologies suitable for an IFE power plant
  - Prototype concepts and designs for application in an IRE
- Conceptual design was completed in CY00; final design in 2001





Direct drive target sabot

A gas-gun is selected as a demonstrated technology to acquire injection/tracking data

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Summary and conclusions

Target Fabrication

- Demonstrating a credible pathway for mass-production of IFE targets:
  - Five-year plan
  - Proof-of-principle fabrication steps being taken
  - Issues, e.g., gold permeability, being examined and backups developed
  - Industrial mass-production technologies being evaluated
  - Chemical process modeling and fab facility cost estimates started
  - High-volume filling methods being studied in detail

Target Injection

- Analyses of target survival during injection have shown "success windows"
  - Next step is acquisition of data on DT response and reflection
- Design of an injection and tracking system is proceeding as planned
  - Conceptual design review completed with minor comments

…. Significant progress is being made towards demonstrating practical and self-consistent scenarios for target fabrication and injection

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