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Information Technology for Engineering and Manufacturing

Multidisciplinary Design of Fire Control and Missile Systems using a Knowledge-based Engineering Architecture

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https://embastion.external.lmco.com/methods-group/wde

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Summary

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Basic efforts:

•Development of a Web-based Design Environment (WDE) that can be used (both by the DoD and commercial companies) in multidisciplinary, distributed, collaborative design activities throughout the world-wide-web.

•Application and demonstration of the use of WDE for performing both Conceptual Missile Design (IMD – Interactive Missile Design) and Conceptual Fire Control Design (IGD – Interactive Gimbal Design) at Lockheed Martin Missiles & Fire Control (LMM&FC).

Leverage:

•WDE will build upon and hence leverage significant investments already made in a product, AML, an Adaptive Modeling Language, offered commercially by TechnoSoft. The WDE incorporation of IMD and IGD, presently developed in AML, will build upon and also leverage significant investments made by the DARPA RaDEO-IGD Program, AM**3 and LMM&FC.

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Overview of AML
(Adaptive Modeling Language)

AML Review

- AML provides an object oriented engineering framework to capture and organize the vital engineering knowledge and processes within a unified object-oriented part model.

- AML's underlying virtual layer architecture enables the seamless integration of engineering tools to automate the entire engineering cycle from conceptual design to production.

Engineering Knowledge

Domain knowledge

- Knowledge related to the product and process design as used within the various disciplines.

Application knowledge

- Knowledge related to the use of the various engineering tools as applied to the product and process design.

Collaborative Engineering

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The AML's framework enables engineers from various disciplines (design, analysis, and process planning…) to simultaneously interact in a dynamic environment supporting concurrent and collaborative engineering.

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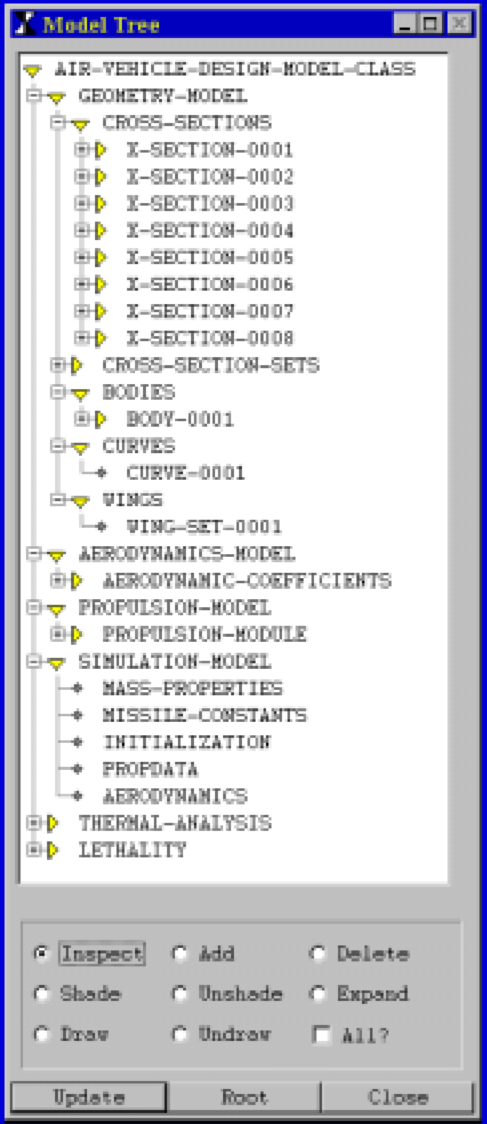
Distributed Dynamic Models & Dependency Tracking

- Models, Objects, and Properties can be dynamically added and/or edited independent of the order of dependency.
- Forward and backward dependencies at any level are automatic.
- Models, Objects, and Properties are dynamically managed across distributed sites amongst concurrent/non-current users.
- When a Model, Object or Property is changed, all dependent Models, Properties, and Objects are notified. These are recomputed only when demanded.
- The AML part model is divided into sub-models each of which captures the strategy of one's engineering discipline.



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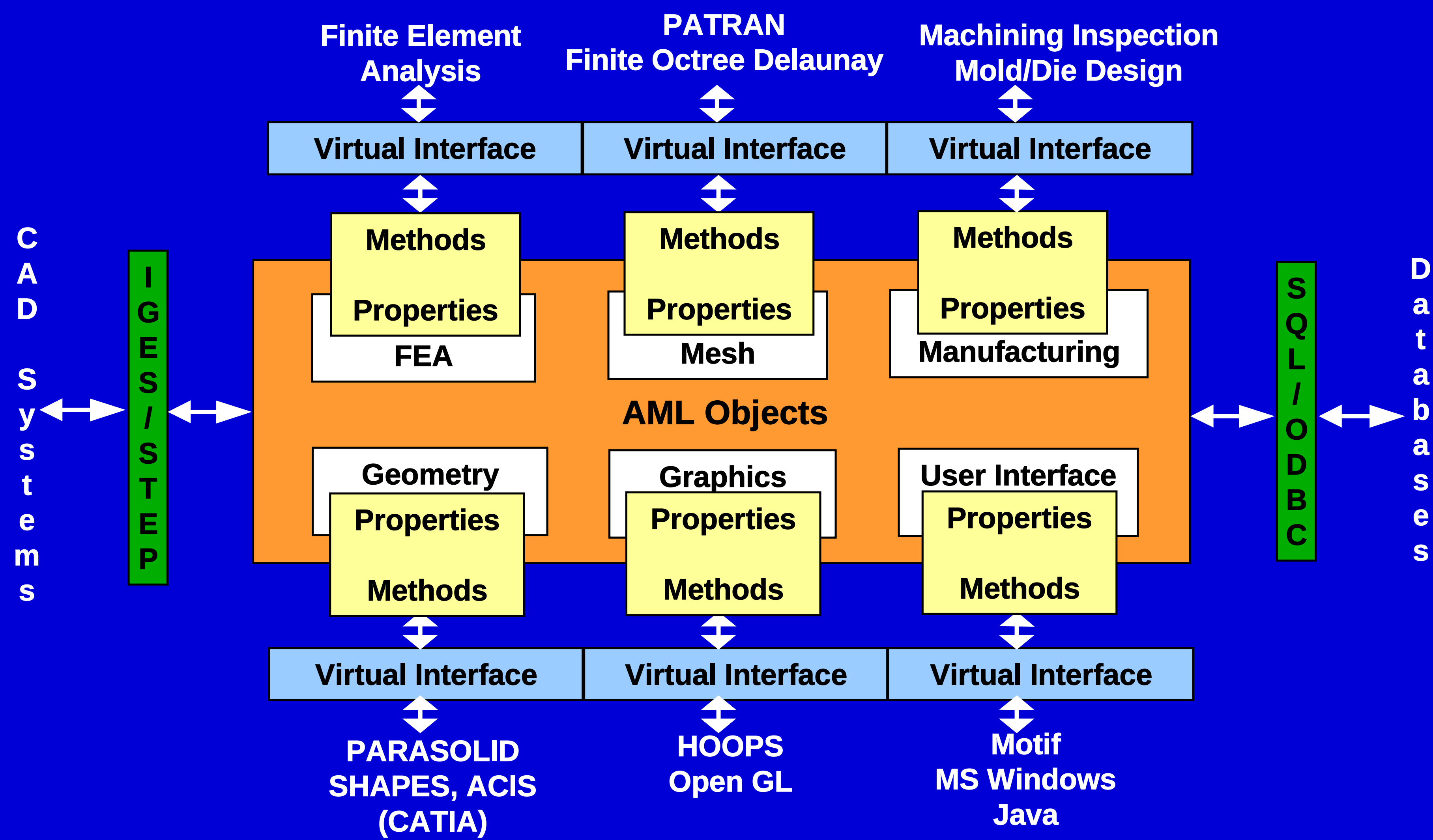
AML’s General System Architecture



Overview of WDE Functionality

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WDE Features

- Object-Oriented Modeling
- AML Framework Architecture for WDE
- Modular Architecture of WDE
- Virtual Layer Architecture of WDE
- Distributed Models of WDE
- Multi Users, Single Unified Model of WDE
- Event Triggers and Event Manager of WDE
- Dependency Tracking and Demand Driven Computation of WDE
- Model Querying of WDE
- Security of WDE
- Conflict Resolution, Optimization, Sensitivity Studies of WDE
- Scalability of WDE
- Large Data Models of WDE
- WDE Activity Based Cost Modeling
- Integrating New Design Tools in WDE
- Design Process Capture of WDE
- Automatic Documentation of WDE
- WDE integration with SAVE, SBD, CORBA, DCOM

Interactive Gimbal Design (IGD)

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Functional Capability of the IGD System

Requirements
- Optical – aperture, field of view, wide, narrow, magnification, zoom
- Servo – minimum natural frequency, transfer functions, timing
- System – range, stabilization, field of regard
- Mechanical – g loads, frequency loads, random loading, shock, number of axes
- Thermal – optics temperature, heat dissipation, gyro and torquer, electronics

Previous Gimbal Designs

Standardized Databases
- Torquers
- Gimbals
- Bearings
- Gyros
- Resolvers
- Lenses
- Mirrors
- Belts

Optical Design
- Prescription for lens design
- Mirror design
- Field stops
- Fold lines
- Geometry of optical elements
- Restricted volumes
- Geometry of optical train
- ACCOS-V

Interactive Gimbal Design
Run-time executables of off-the-shelf software products integrated to form a multidisciplinary, interactive software tool. The integration will allow for the concurrent assessment of design decisions and offer a multidisciplinary optimization process.

Gimbal Mechanical Design
- 3-D geometry of gimbals
- Assembly of gimbals and optical train
- Stabilized mirror, stabilized platform
- Two-axis gimbals, drive ratios
- Bearing selection with size, mass props, port for lens cell, friction-to-inertia ratios, stiffness
- Torquer selection with size, mass props, torque rate, voltage requirement, analysis
- Assembly and manufacturing considerations
- Gyro selection with size, noise, mass props, accuracy, sampling rate, digital, analog, location, quantification of size, noise accuracy, sampling rate, inertia-to- friction ratios, digital, analog

Dynamic Analysis
- Line of sight jitter calculations
- Natural freq of components and assy
- Incorporation of optical equations
- Lens and mirror distortion
- Flexibility of bearings
- Transfer functions for servo
- NASTRAN
- DADS

Servo
- MATRIX-X & DADS

Thermal Analysis
- Maximum temperature of optical components
- Thermal gradients in optical components
- Thermal distortion of optical components
- Cooling of torquers, gyros, and optical geometry
- Cooling of bearings
- FEM/SINDA

Materials Database
- M-Vision

Manufacturing Processes
- Automatic generation of machining (NC) and inspection (CMM) programs
- Capability to monitor and improve product designs (early)
- Reduce process cost through simulation (manufacturing plans)
- Early assessment of materials and processes
- Automatic part setup for fixturing/tooling

Interactive Missile Design (IMD)

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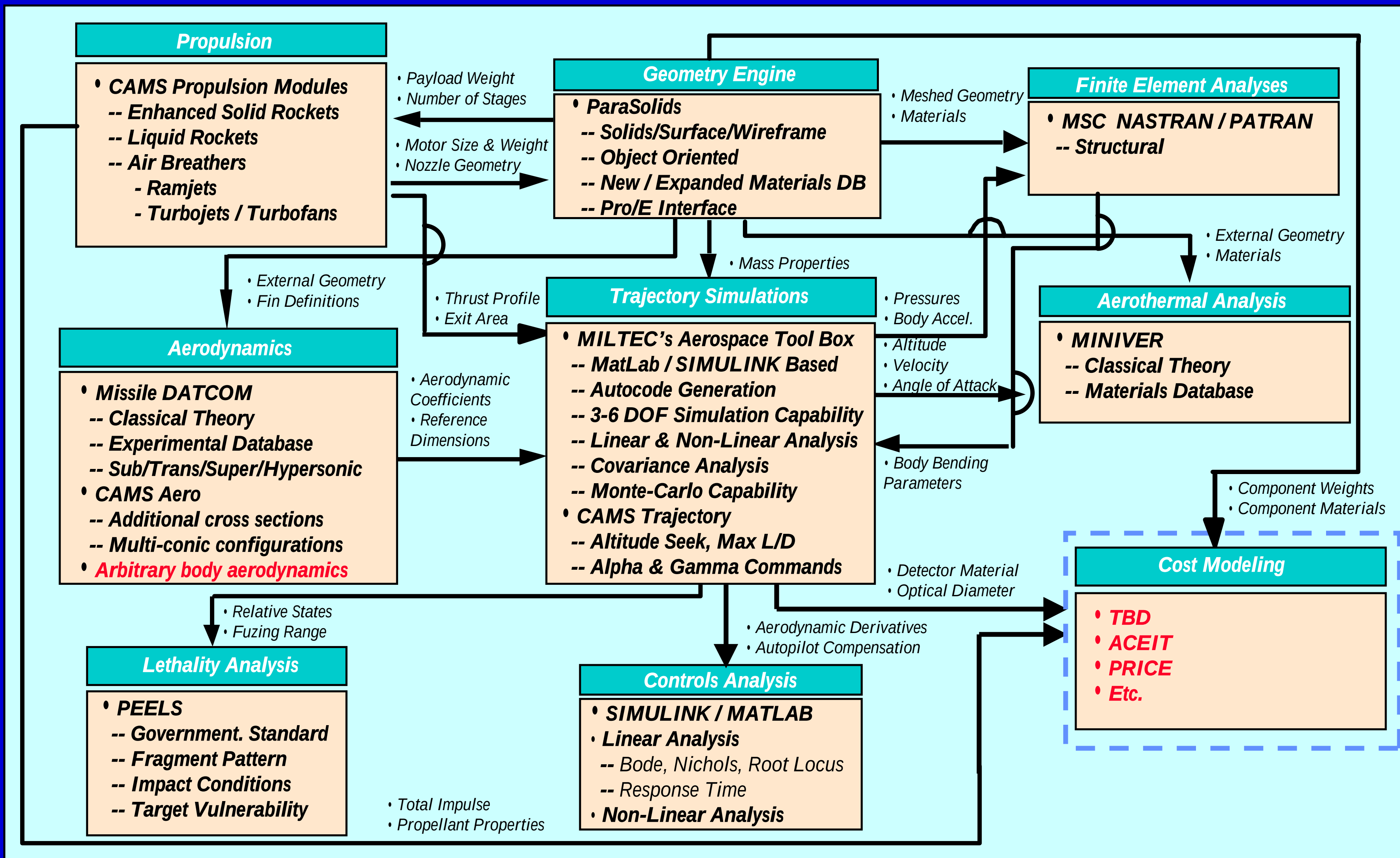
IMD (version III) Software Architecture



Interactive

Missile

Design

Environment

Video

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AML GUI Builder Demo

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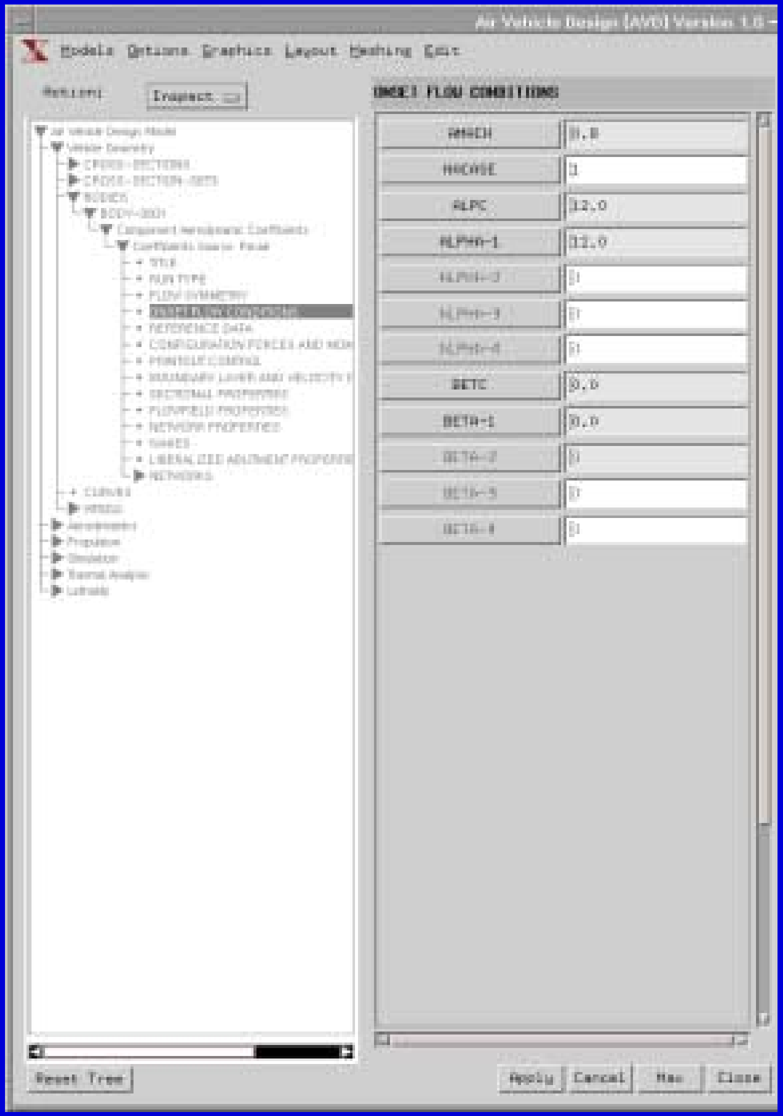
New AML GUI Functionality Example

```
  label "ONSET FLOW CONDITIONS"

        ;;; Onset flow conditions
        (amach :class 'panair-computed-data-property-class
               label       "AMACH"
               formula     (the superior superior current-amach
                     (:error 0.0))
               description "Mach Number: MACH"
               )
        (nacase :class 'panair-editable-data-property-clas
               label       "NACASE"
               formula     1
               description "Number of solutions: CASE"
               )
        (alpc :class 'panair-computed-data-property-class
               label       "ALPC"
               formula     (the superior superior current-alpc
                      (:error 0.0))
    description "AOA Direction of Compressibility
ANG"
               )
        (alpha-1 :class 'panair-computed-data-property-cla
               available     (>= ^nacase 1)
          formula    (the superior superior current-alpc
                     (:error 0.0))
               description "Angle of Attack (degrees), Solution

               )
```



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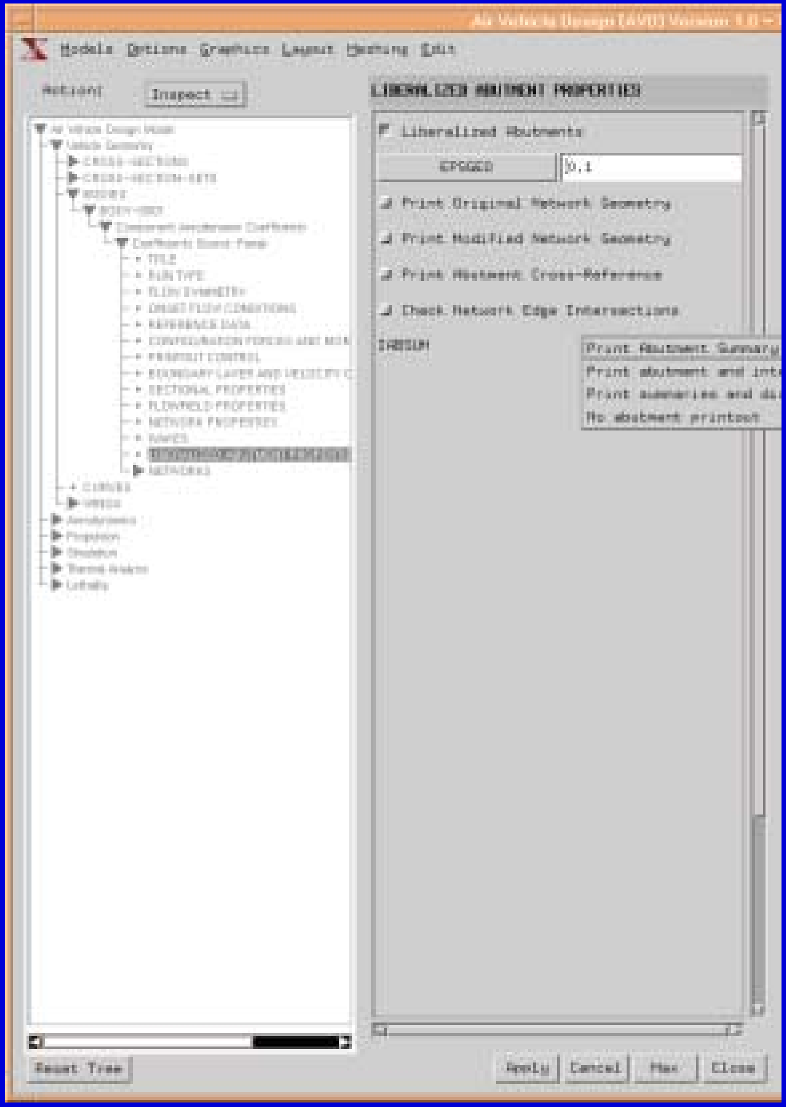
New AML GUI Functionality Example

```
label "LIBERALIZED ABUTMENT PROPERTIES"
  short-label "LIBERALISED ABTMNT. PROPS."

  (liberalized-abutments? :class 'panair-flag-data-property-class
                                             label       "Liberalized Abutments"
                                             description ""
                                             )

  (epsgeo :class 'panair-editable-data-property-class
                description "Absolute Value of Dimensional Tolerance: 0.1 (default)
           to 3.0 percent of diagonal length of smallest panel"

                formula 0.1
                available? ^^liberalized-abutments?
                )

  (igeoin :class 'panair-flag-data-property-class
                available?   ^^liberalized-abutments?
                nil-value 0
                true-value 1
                label "Print Original Network Geometry"
                )

  (igeout :class 'panair-flag-data-property-class
                available?   ^^liberalized-abutments?
                nil-value 0
                true-value 1
                label "Print Modified Network Geometry"
                )
```



Web-enabled Interactive Missile Design (IMD)

Features:

- External geometry
- Vehicle Aerodynamics
- Propulsion Analysis
- 3 – 6 DOF Simulation
- Controls Analysis
- Aero-thermal Heating Analysis
- Blast Frag Warhead Lethality Analysis
- Airframe Structural / Dynamic Analysis

Demonstration:

- Two client, collaborative session with common model
- Real-time access design changes (missile nose & propulsion system)
- Simultaneous, dual model, real-time collaborative session

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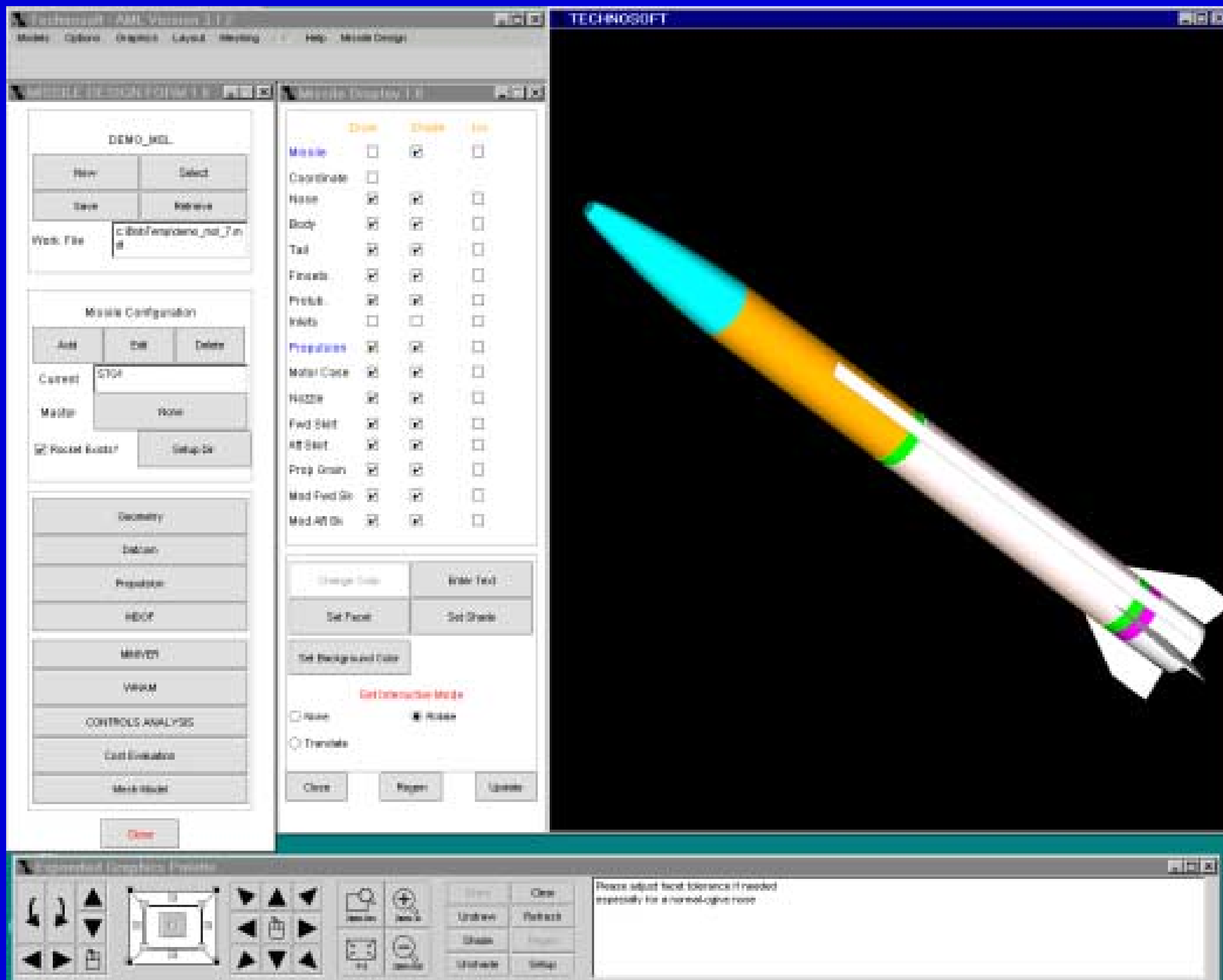
Client 1 loads missile model



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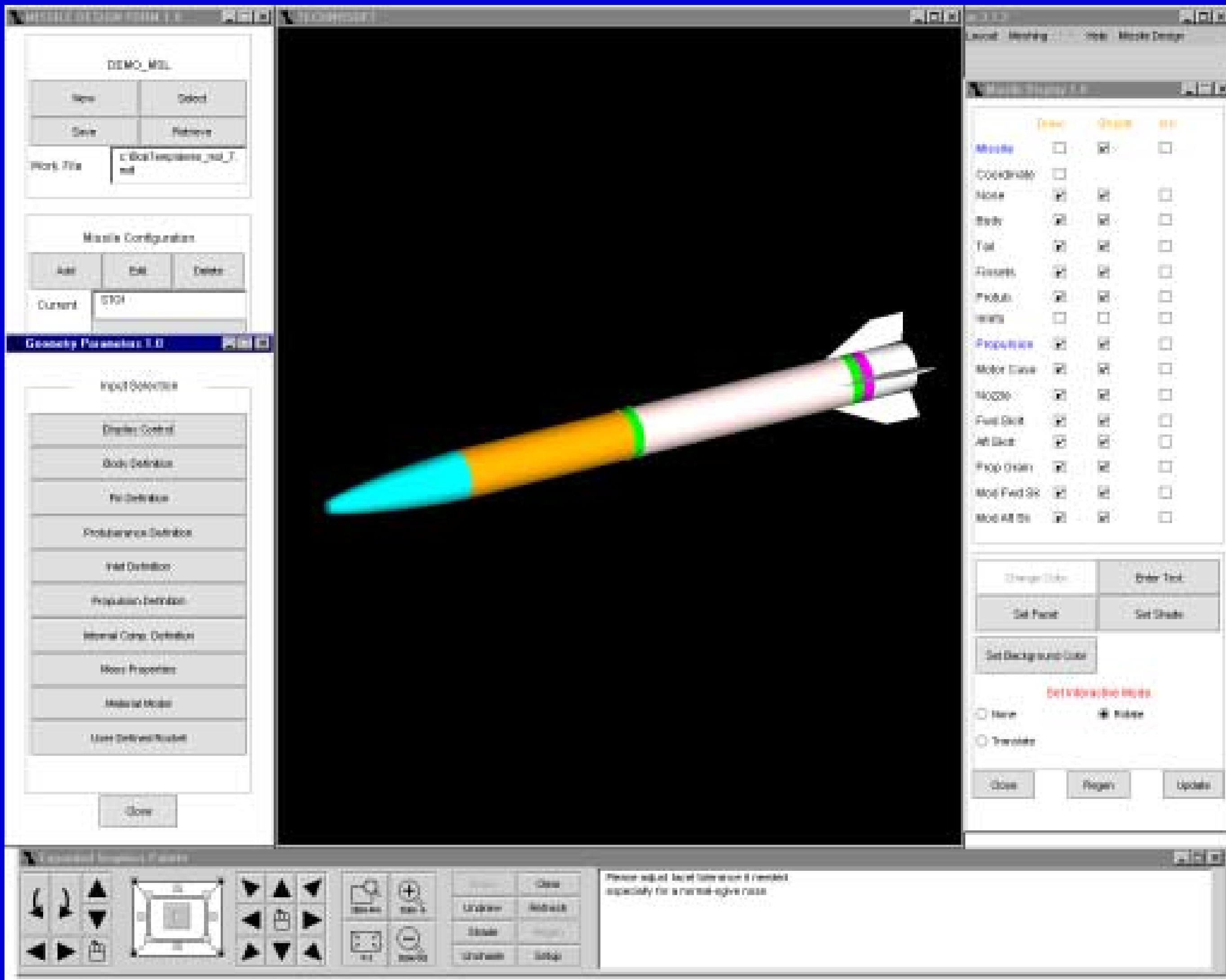
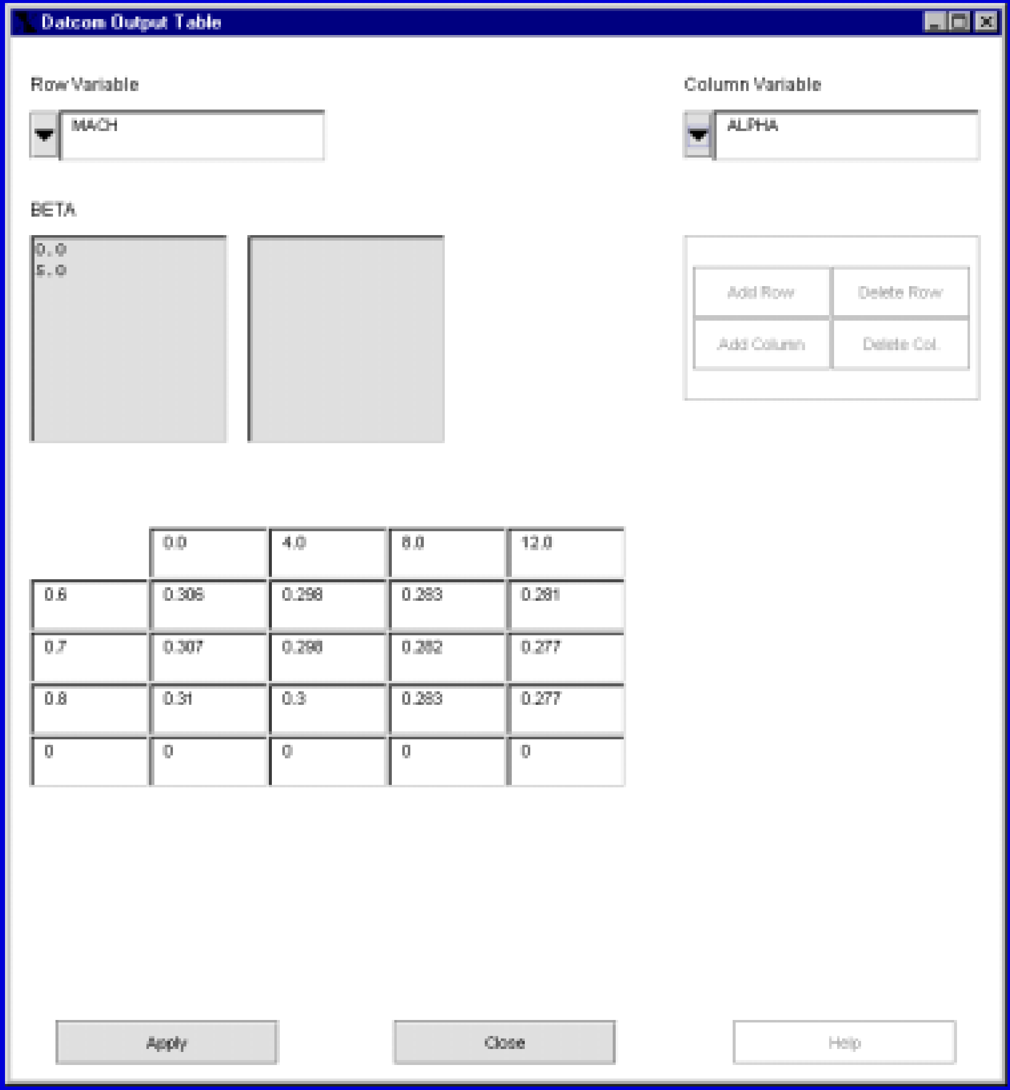
Client 2 also loads same model



Client 2 makes a DATCOM run and displays Ca coefficients



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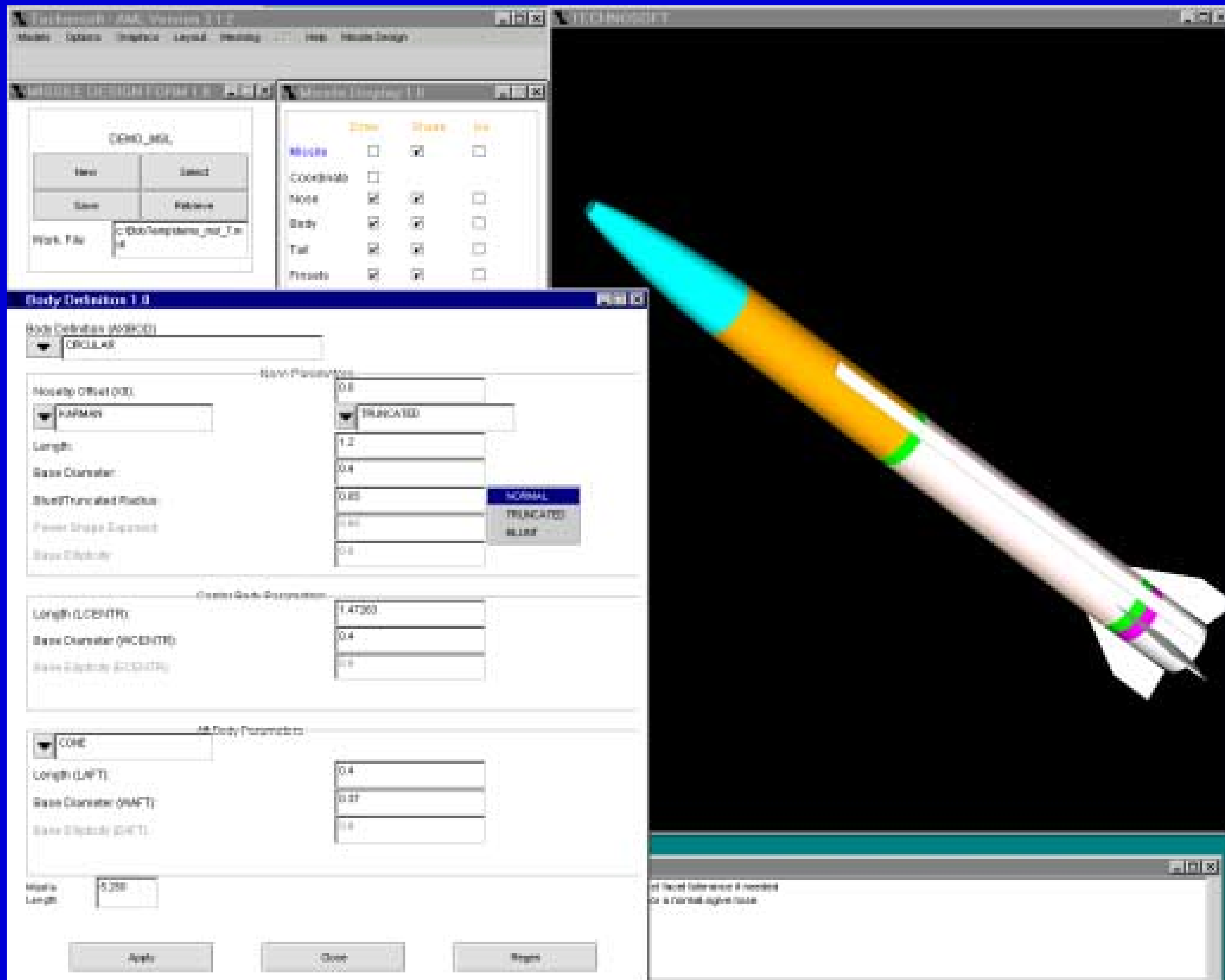
Client 1 modifies missile's nose



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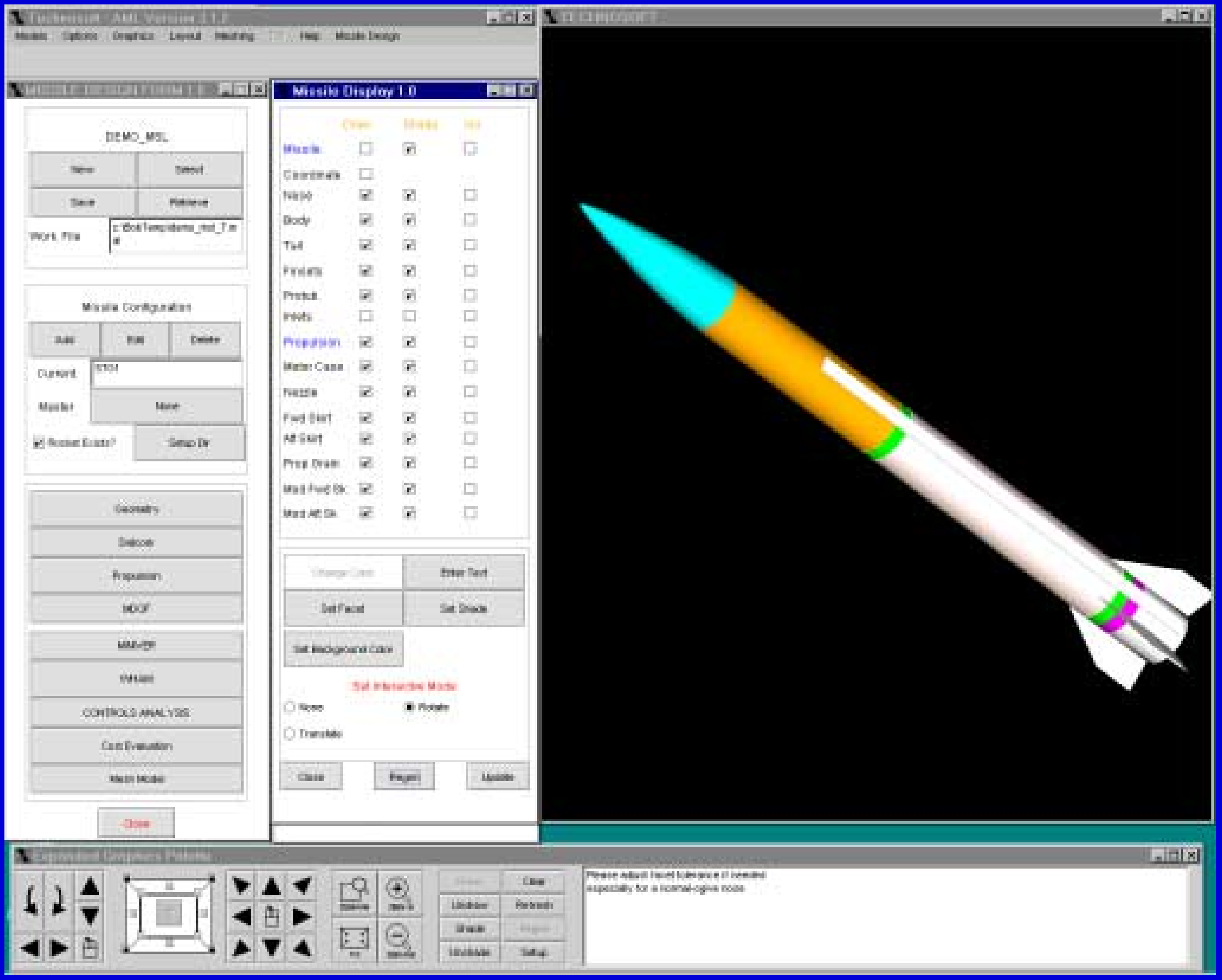
Client 1 displays model change



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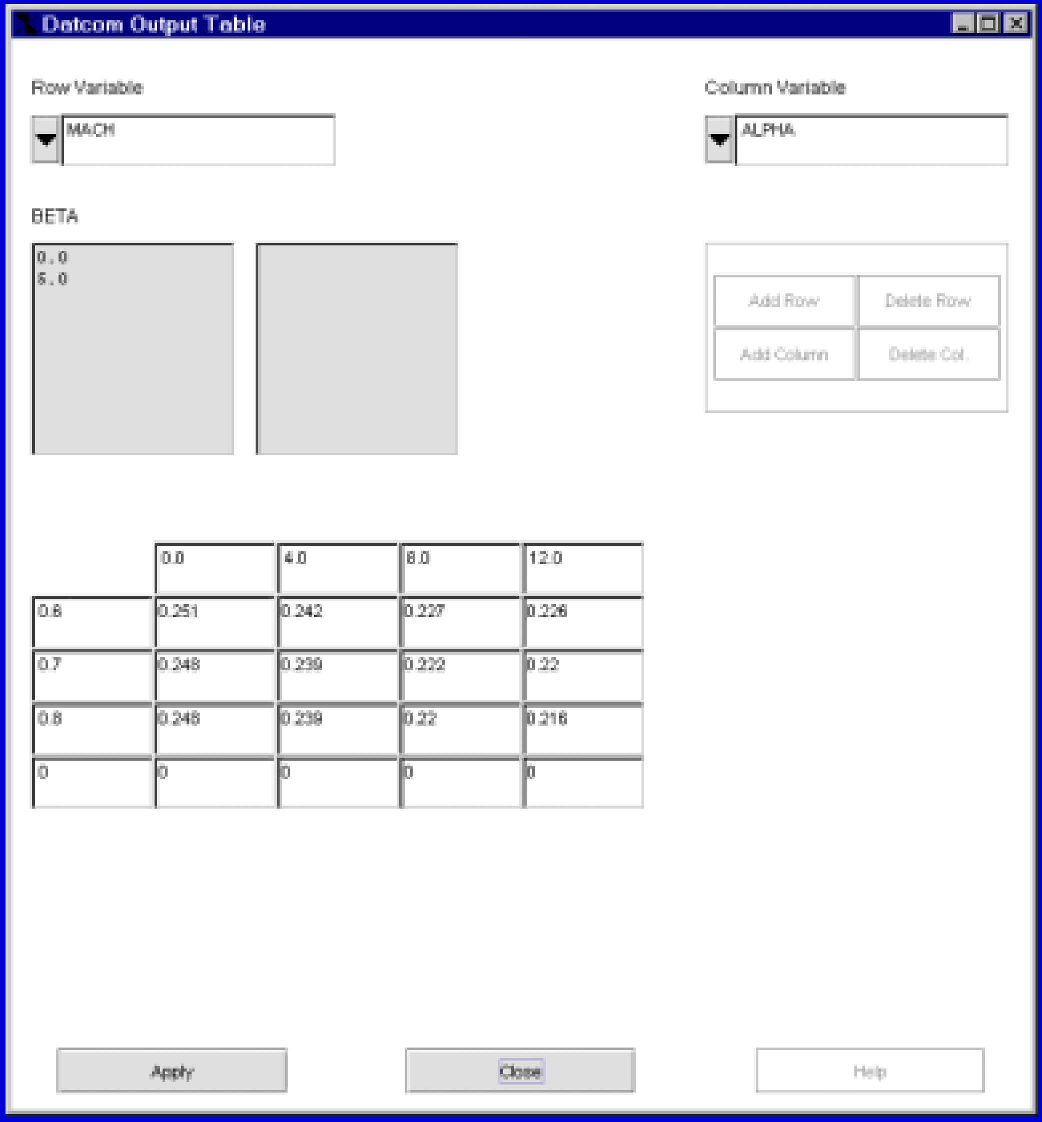
Client 1 makes DATCOM run and displays Ca coefficients



	0.0	4.0	8.0	12.0
0.6	0.251	0.242	0.227	0.226
0.7	0.248	0.239	0.222	0.22
0.8	0.248	0.239	0.22	0.216
0	0	0	0	0

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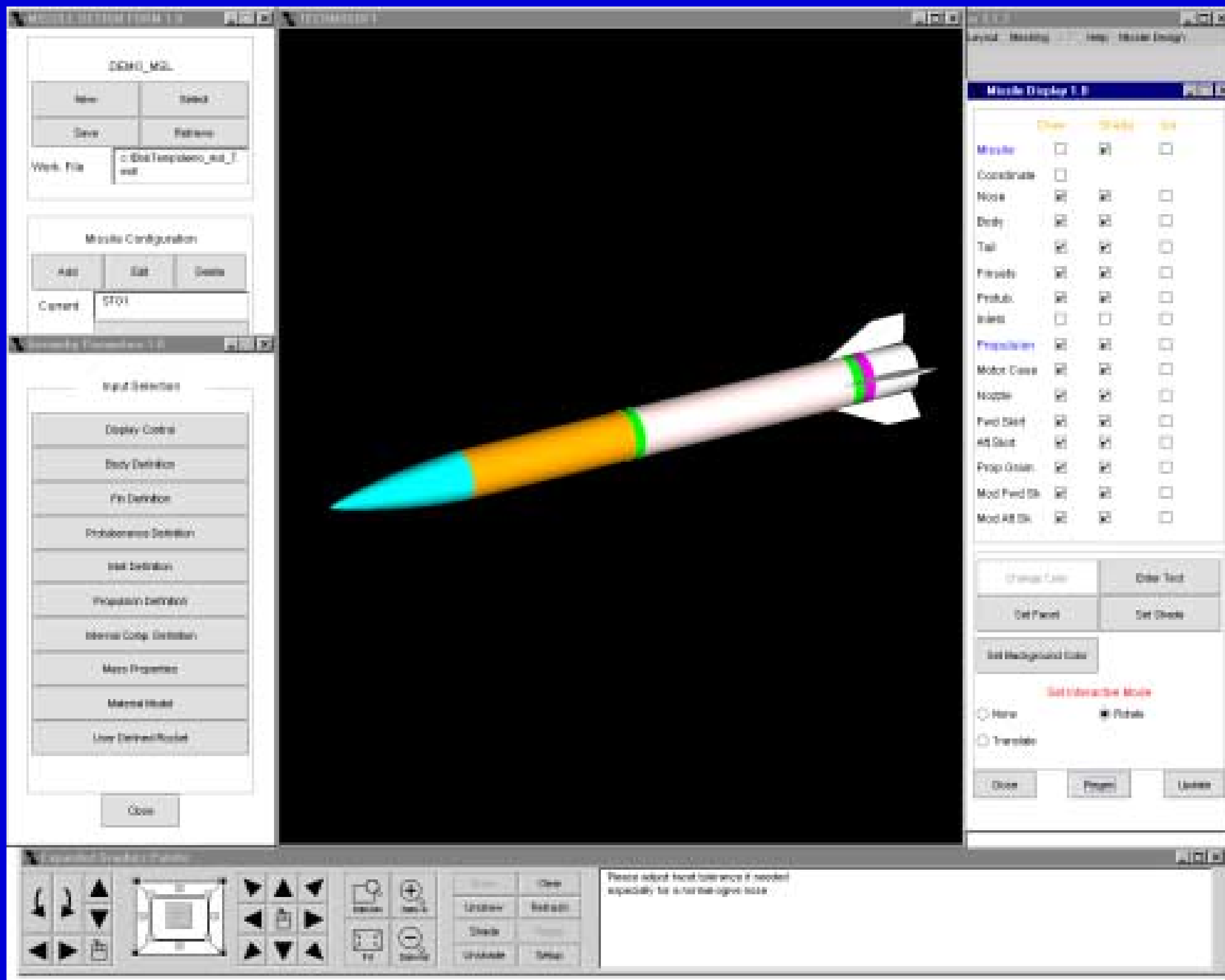
Client 2 displays model after Client 1 modifies nose



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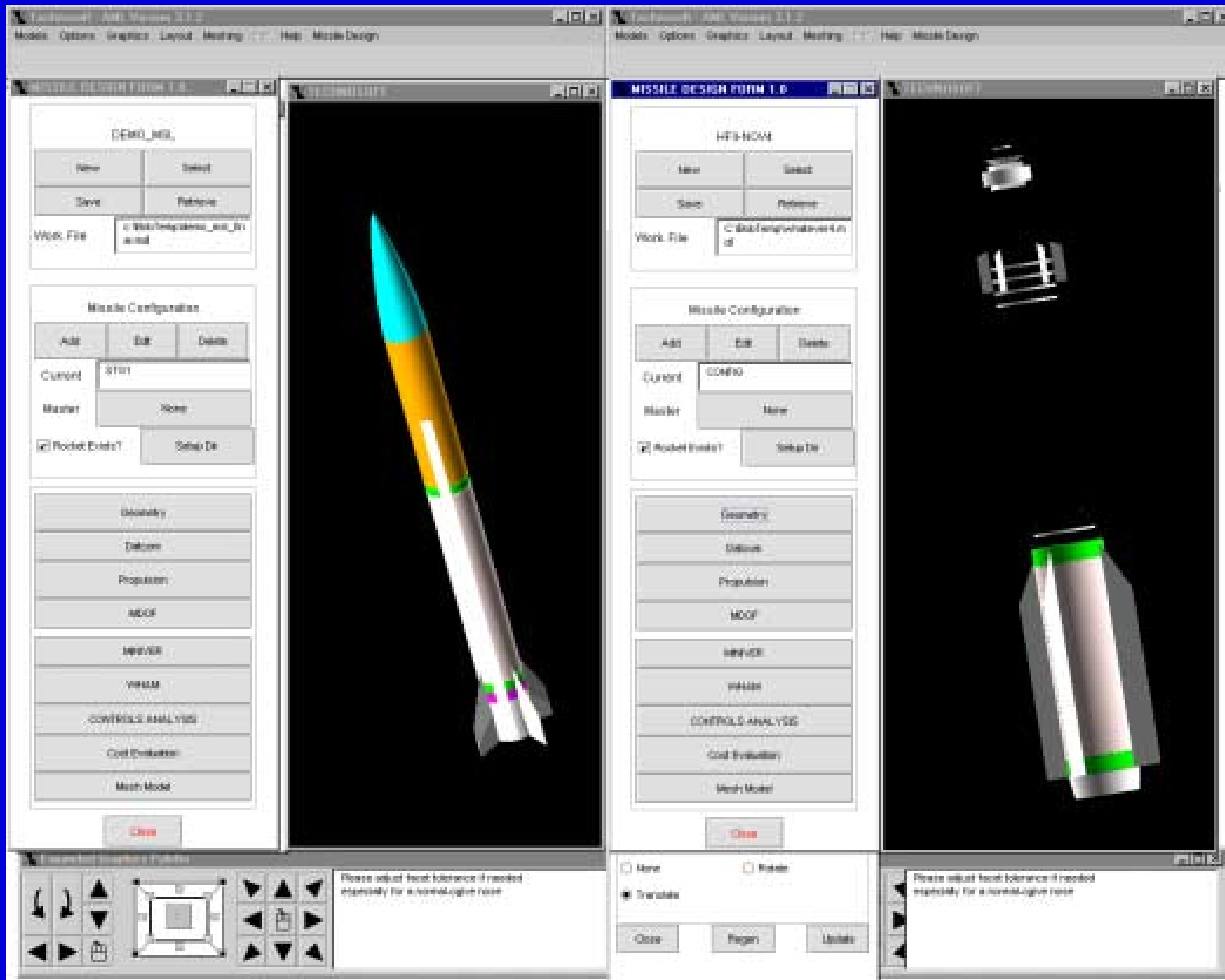
Simultaneous, dual model, real-time collaborative session



Thin-Len Example

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Web-enabled “Thin-Lens” Design Tool

Features:

- Thin-Lens Physics (Lens-Power, Refraction, Paraxial Rays)
- Lens, Folds, Mirrors, Aperture-Stops, Target Surfaces
- Automatic Optical-Axis (unfolded or folded)
- Automatic Chief-Ray, Axial-Ray
- Merdional Ray Traces
- Thick-Lens Recipes
- LENO file output

Demonstration:

- 2-Client, Collaborative session, Common-model
- Real-time access design change (placement of fold-mirror)
- Maintain focus-point alignment with reference-plane.
- Resultant robust design, with thick-lens LENO output.

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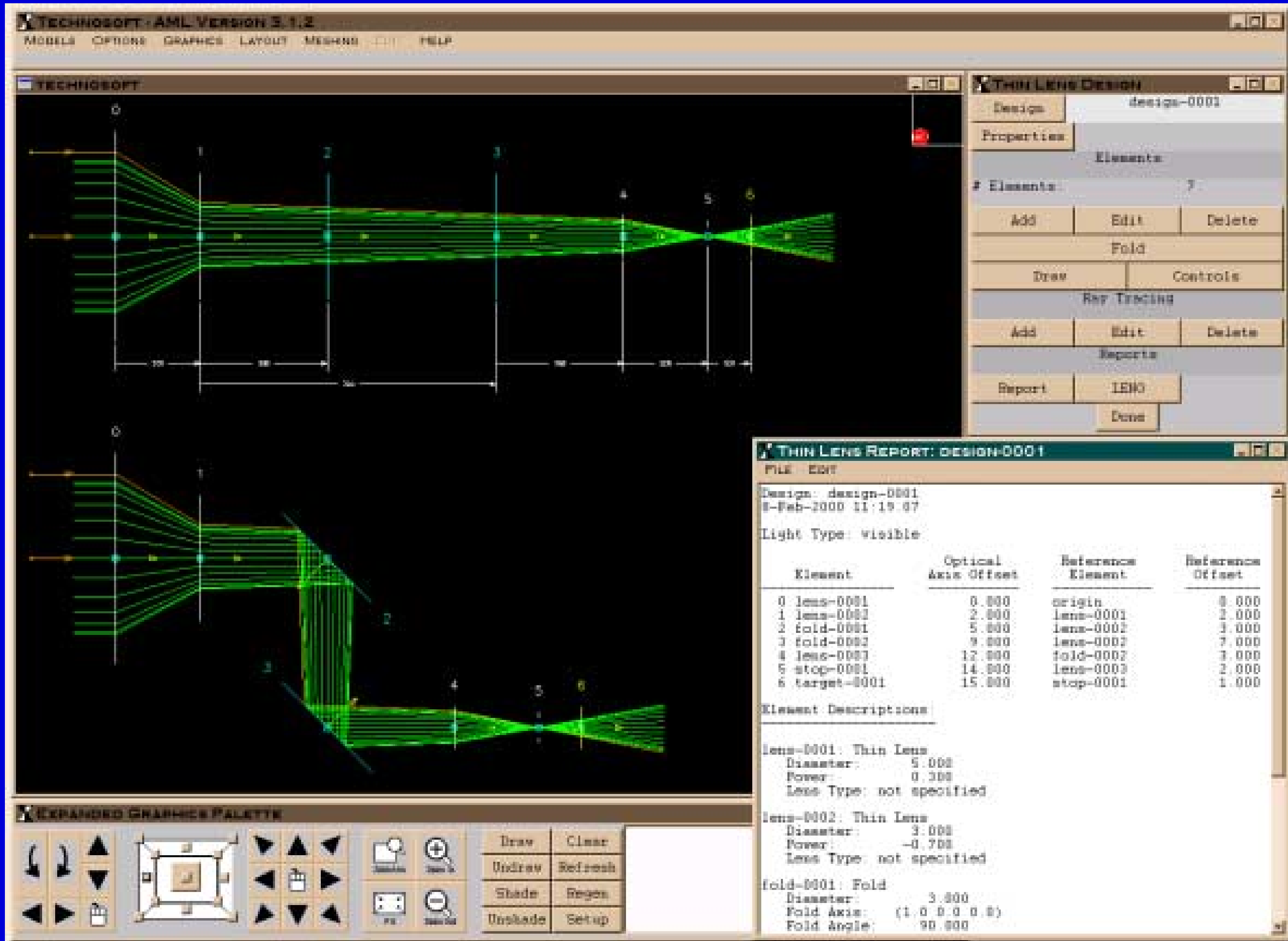
Original Design (unfolded & folded)



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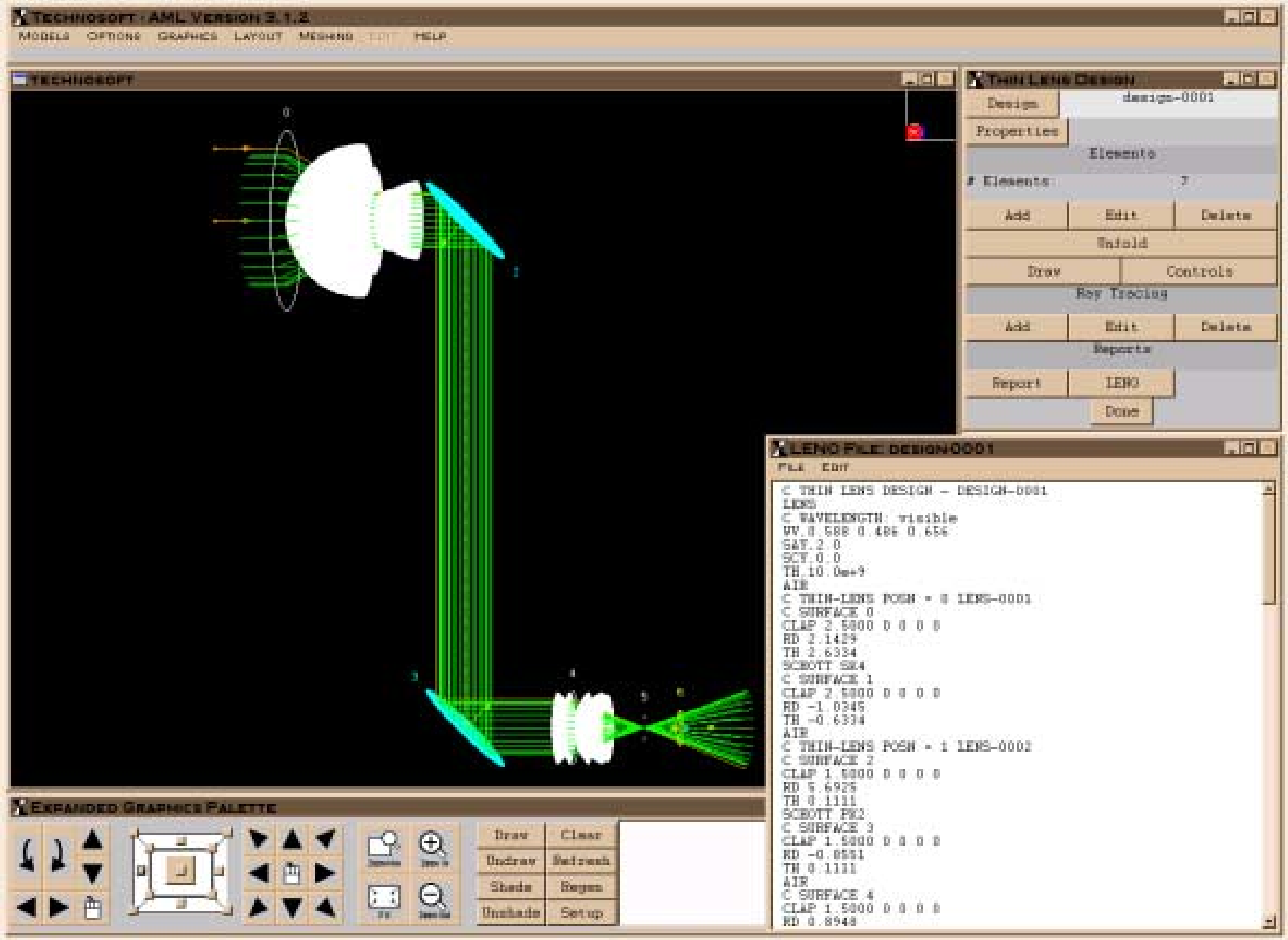
Modified Design (thick-lens, LENO output)



Overview of
Propellant Burn Simulations

(to be integrated into IMD/WDE)

Propulsion Burn Simulation

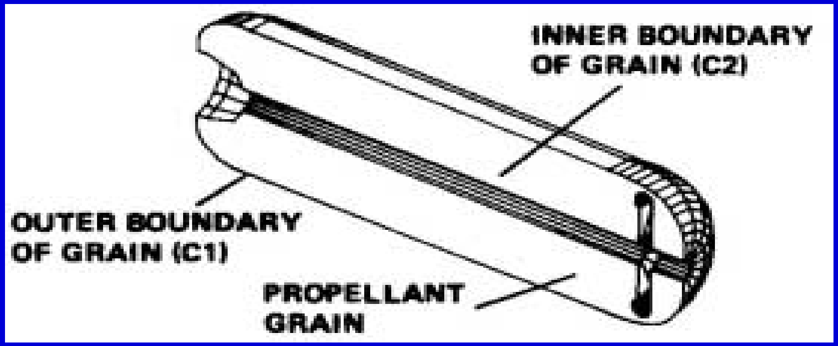
Objective:

- Create a propulsion burn analysis utility using AML
- Integrate burn analysis into IMD-WDE.

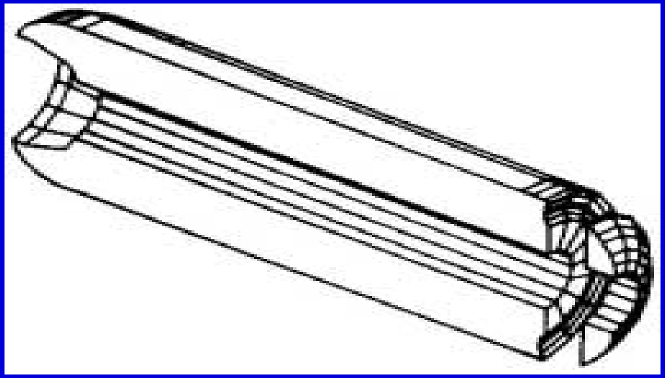
Features:

- Burn Area
- Burn Volume
- Moments of inertia
- Motion of center of gravity (as a function of burn distance)

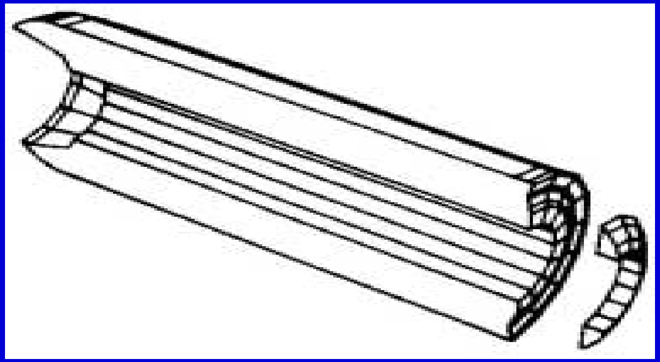
Propellant-grain (cross-sections)



1. Initial Propellant grain

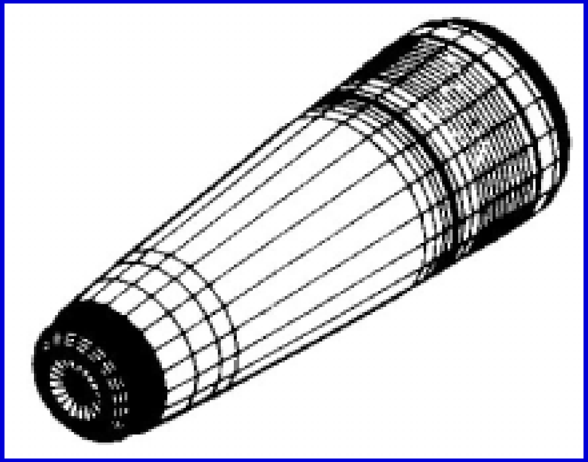


2. Propellant burn after it has grown an amount 1D normal to itself

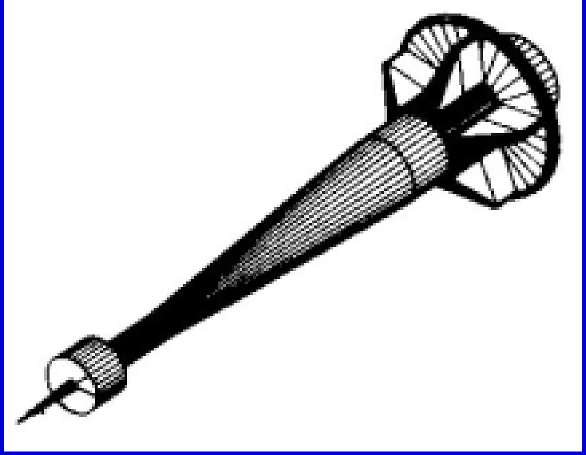


3. Propellant burn after it has grown an amount 2D normal to itself

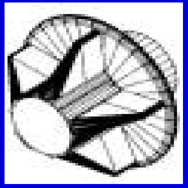
Burn-boundary diagrams



1. Outer boundary

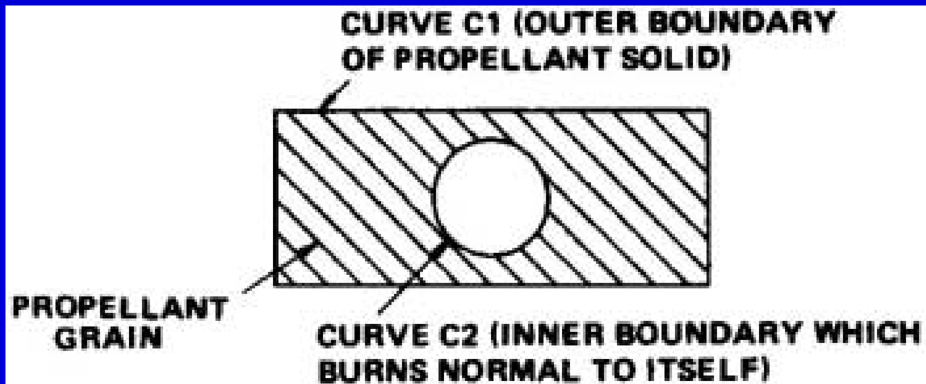


2. Inner boundary

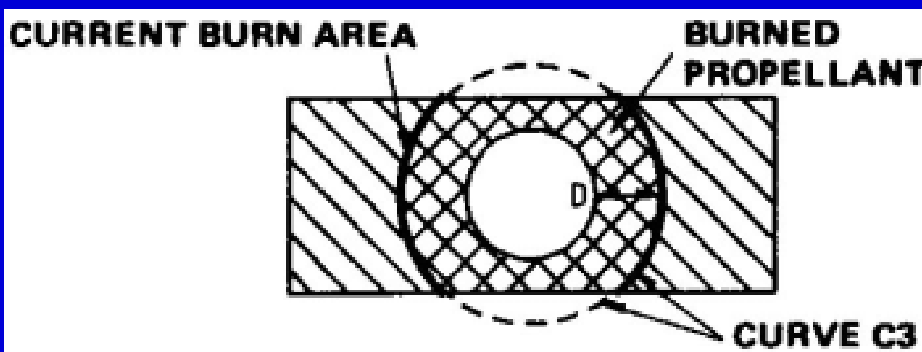


3. Blowup of the star region

Area of Burn



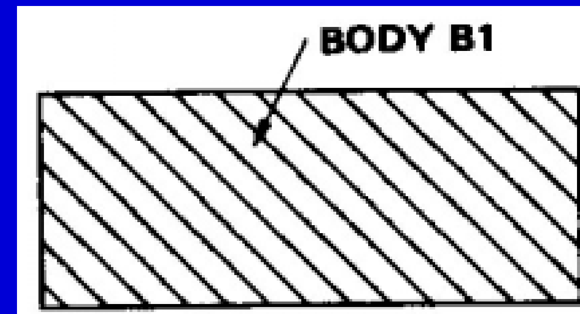
1. Initial Geometry of propellant



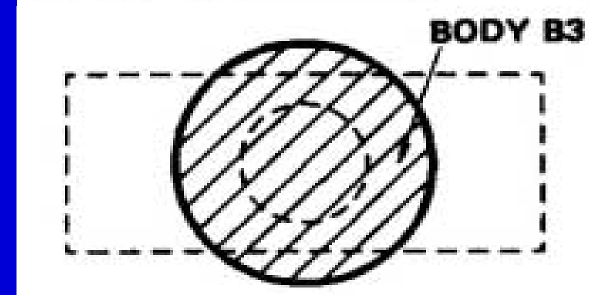
2. Geometry of propellant after initial burn surface has burned normal to itself an amount D

$$\text{AREA of BURN} = \frac{A_{B3} + A_{B4} - A_{B5}}{2}$$

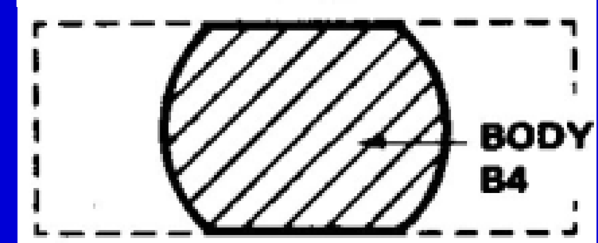
3.



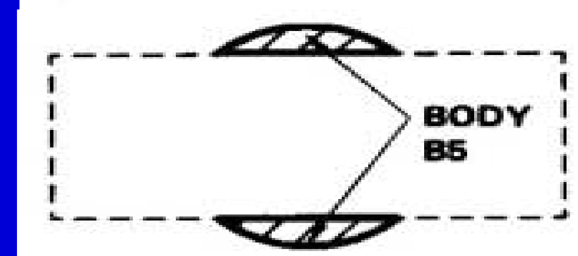
4.



5.



6.



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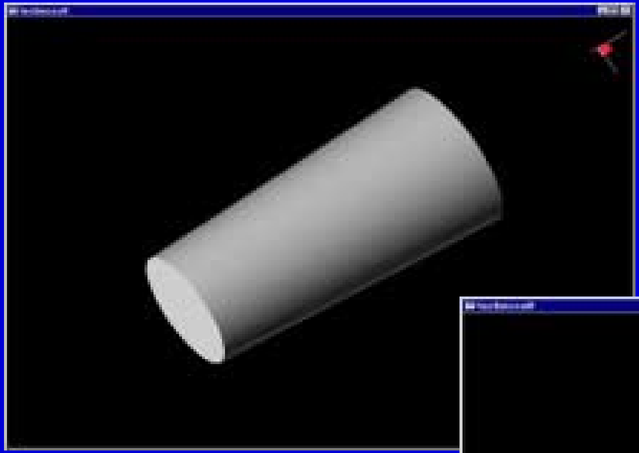
Burn-boundary modeling procedure

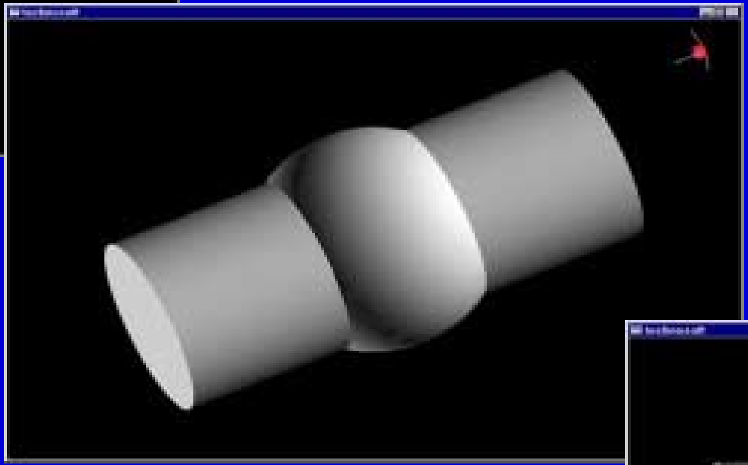
1. Input sub-objects to define outer and inner boundary's of the propellant grain geometry object. The inner boundary sub-object has a parameter for burn distance (normal to surface). Sub-object inherits one of four growth schemes.
2. During simulation, parts of the inner boundary will start to grow beyond the outer boundary, thus use intersection control to get the real shape of the space inside the propellant grain.
3. Get the Shell objects. In order to get the burn surface area, determine the inner boundary shell object and the outer boundary shell object. Then determine the surface area of the space inside the propellant burn.
4. Intersect the surfaces. When the propellant has grown enough, some of the container surfaces are exposed. Those should not be counted in. By intersecting the surface (shell) of the inner space object with the container (outer boundary) determine the exposed container surfaces.
5. Calculate the area as the difference between the inner space area and the exposed container area.

Burn-boundary AML models

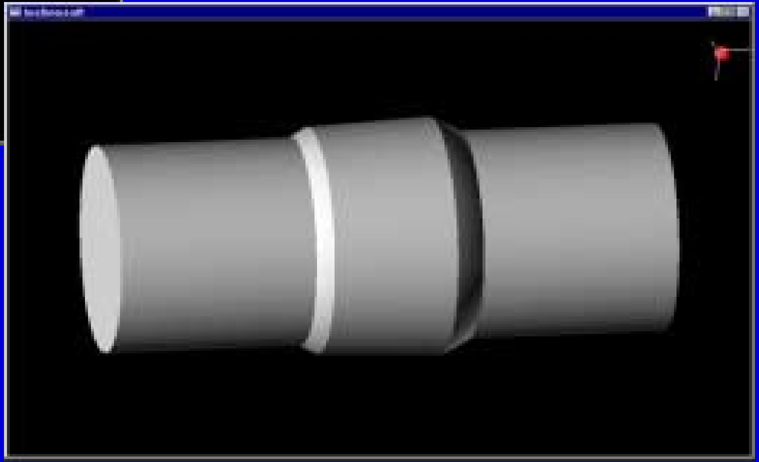
Outer Boundary (truncated cone)



Inner boundary (sample)



Inner boundary after growing.
Note: Inner boundary growth is limited by outer boundary.



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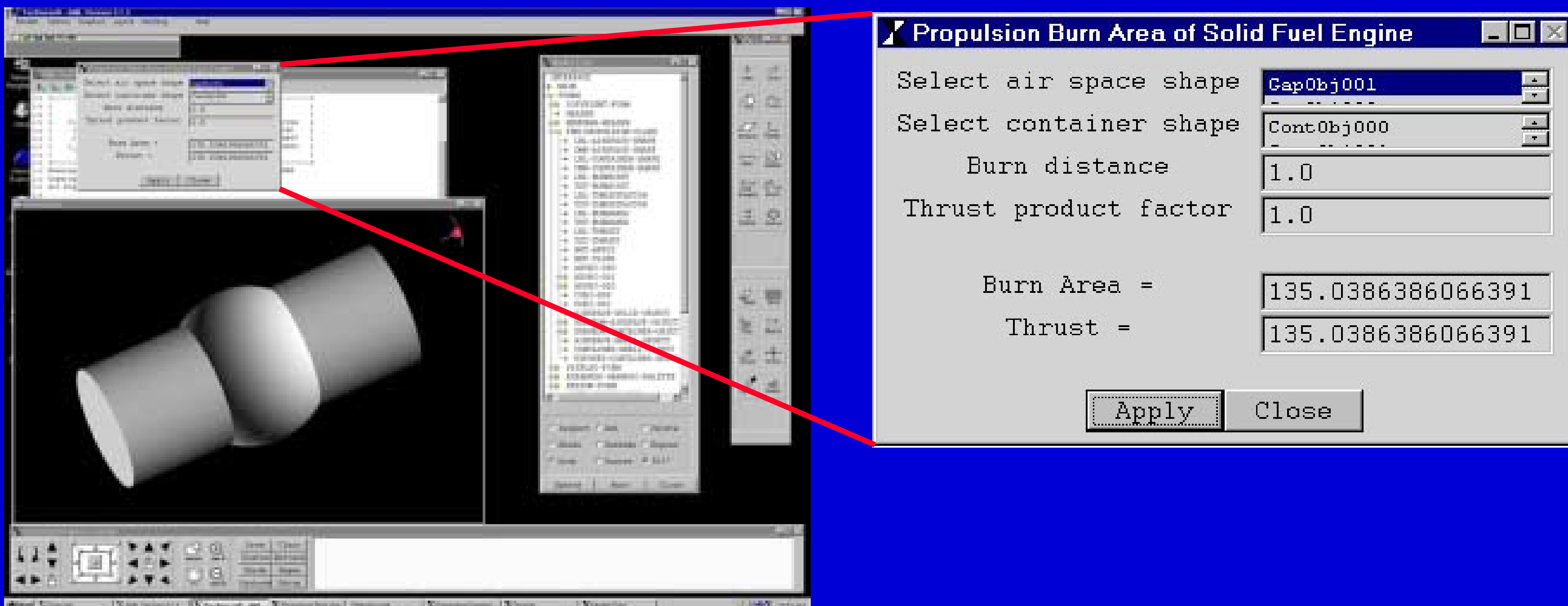
Propulsion Burn AML User Interface

The user interface allows the user to specify parameters such as

- The inner boundary geometry (from an existing list)
- The outer boundary geometry (from an existing list)
- The burn distance
- The thrust product factor

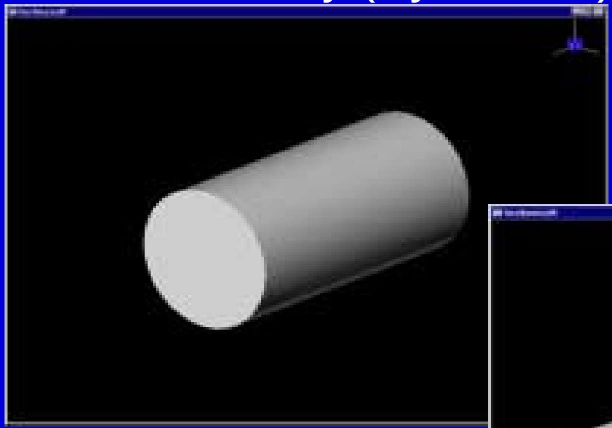
The user interface allow the user to see the results directly. The surface area and thrust is automatically determined.



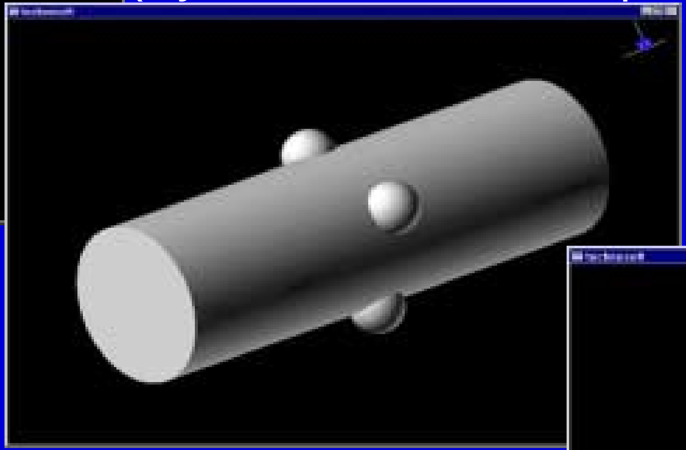
Propulsion Burn Geometry Library

The user should be able to select an inner and outer geometry objects from a wide range of commonly used geometry, both simple and complex objects.

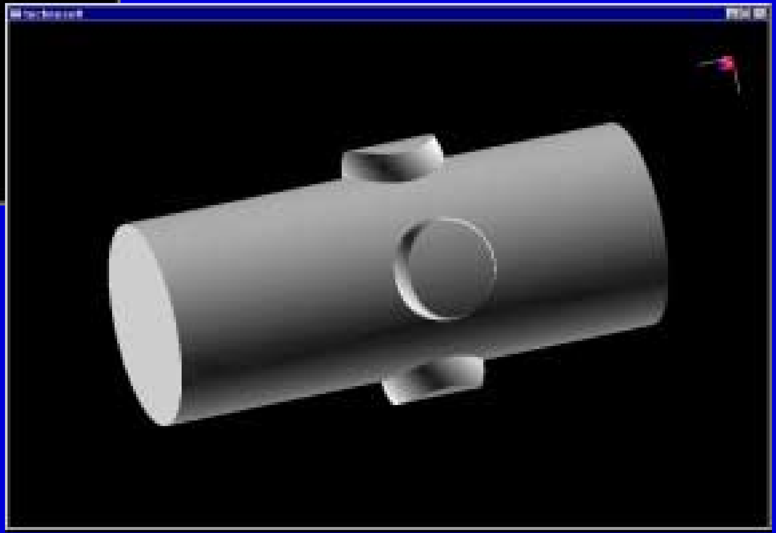
Outer Boundary (Cylindrical)



Inner boundary
(Cylinder with 4 small spheres)



Growth of inner surface
(…starting to be limited
by the outer boundary)



Gimbal Sub-component Database

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Gimbal Subcomponent Database (Web)

Features:

- Thousands of precision-mechanical subcomponents
- MS-Access database→SQL→JavaScript→Browser
- LMC Intranet accessibility

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Demonstration: Search GUI & Diagram

Search→ narrow parameter constraints