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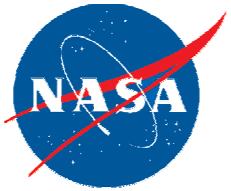

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Thermal Fluids Analysis Workshop
TFAWS 2007

Implementation of STEP-TAS Thermal Model Exchange Standard in Thermal Desktop

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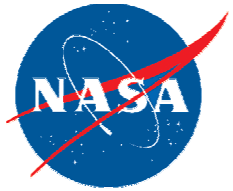
Outline



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- Background of STEP-TAS
- Phase I SBIR Results
- Future Plans

Why Open Standards for Data Exchange

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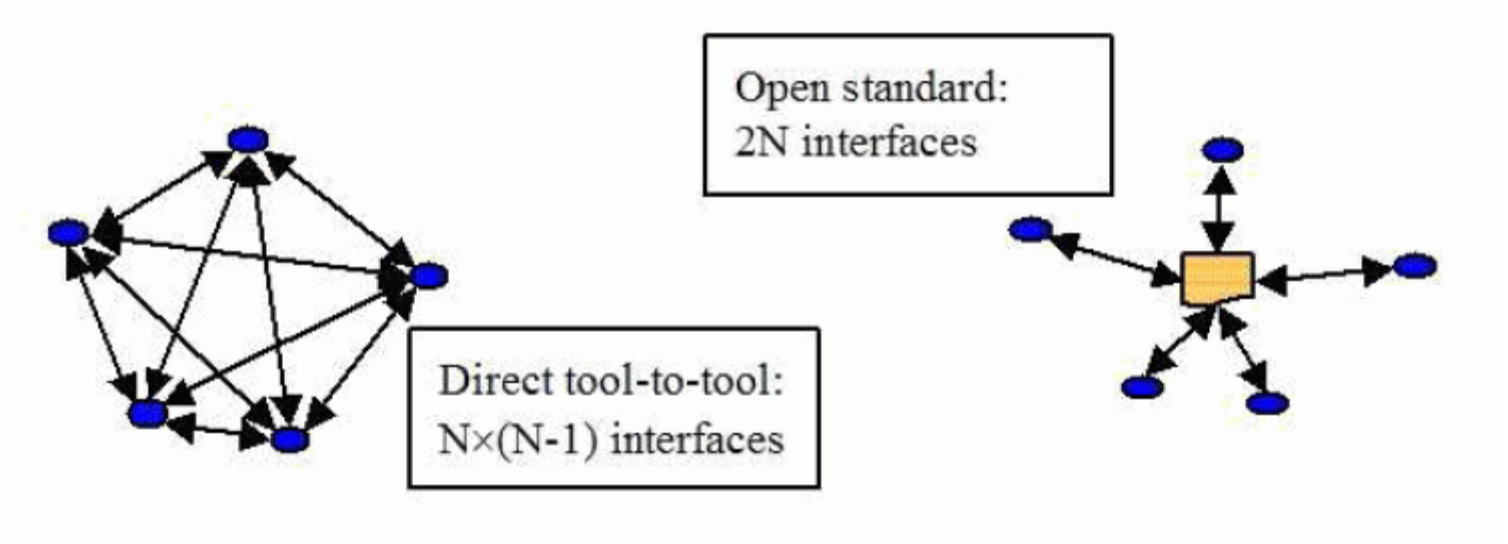
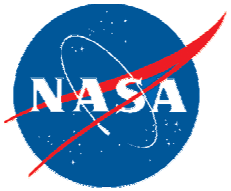


International organization for sanctioning STEP standards

Rigorous data design methodology and modern database techniques ensure a robust and flexible specification not possible with previous formats. "Least common denominator" is avoided by proper design.

Supplied toolkits aid in adoption and implementation

What is STEP



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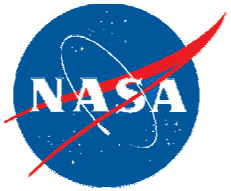
- STEP = STandard for the Exchange of Product model data, casual name for ISO 10303

"STEP is an international standard, which provides an unambiguous, computer-interpretable definition of the physical and functional characteristics of a product throughout its life cycle."

STEP Application



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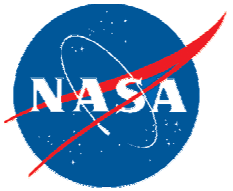
- STEP
  - provides a mechanism that is capable of describing product data throughout the life cycle of a product
  - the description is independent from any particular system
  - it is suitable not only for neutral file exchange, but also as a basis for implementing and sharing product databases and archiving
- STEP standards are developed for specific application domains and referred to as Application Protocols (APs)

What is an AP?



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- An Application Protocol (AP) is a standardized representation of product data in a specific application context.
- It includes:
  - Application Activity Model (AAM): the description of the functionality
  - Application Reference Model (ARM): an application-oriented reference model from a user's point of view
  - Application Interpreted Model (AIM): the representation of the reference model through objects from common Integrated Resources as implementation view
  - Implementation guidelines, conformance conditions for implementations and test suites

STEP Architecture for Aerospace

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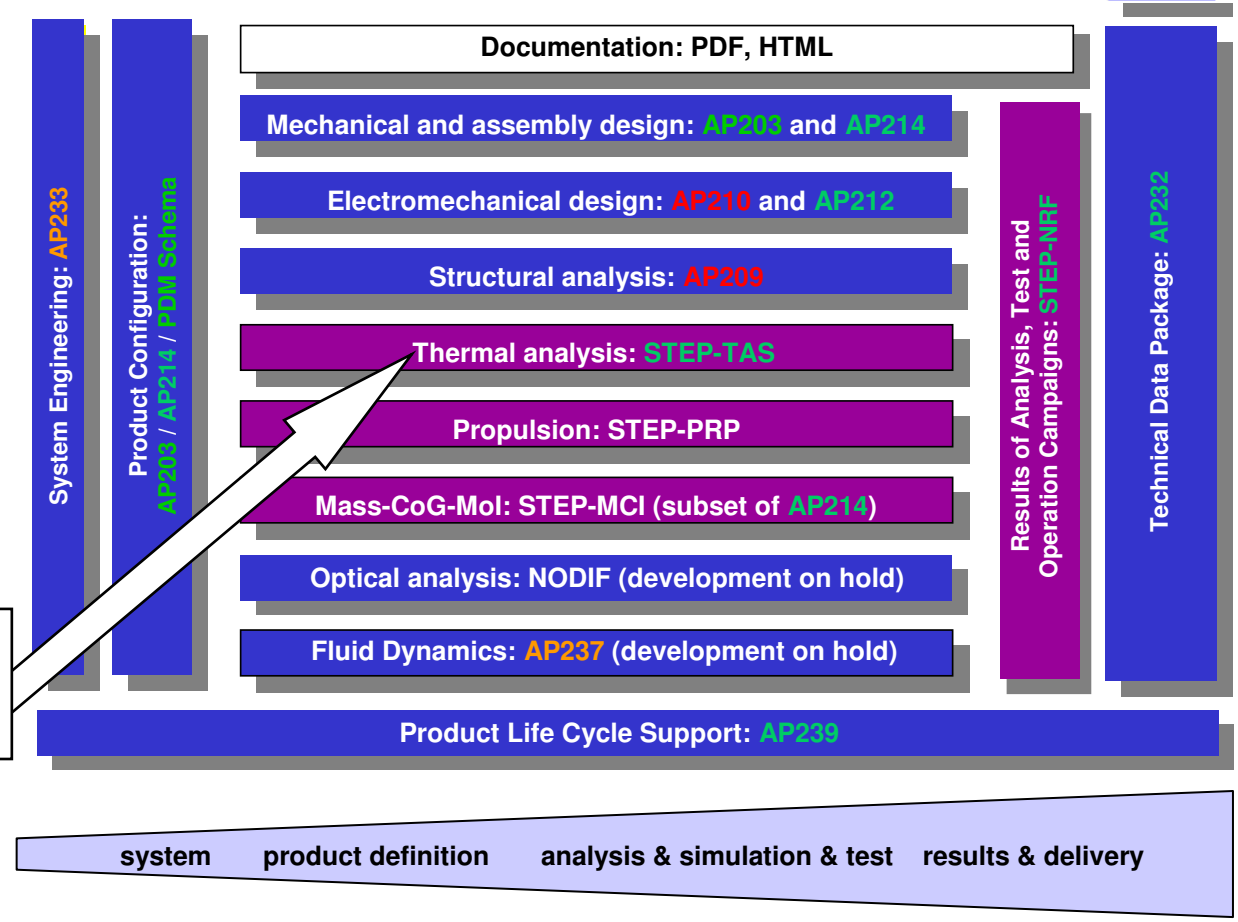
ECSS European Cooperation for Space Standardization

ISO International Organization for Standardization

ECSS
WG E-10-07
Exchange of Product Data

ISO 10303
SC4/TC184
Product representation and exchange



You are here

system → product definition → analysis & simulation & test → results & delivery

In production use **Commercial implementation started** **Final stages of development**

What is STEP-TAS

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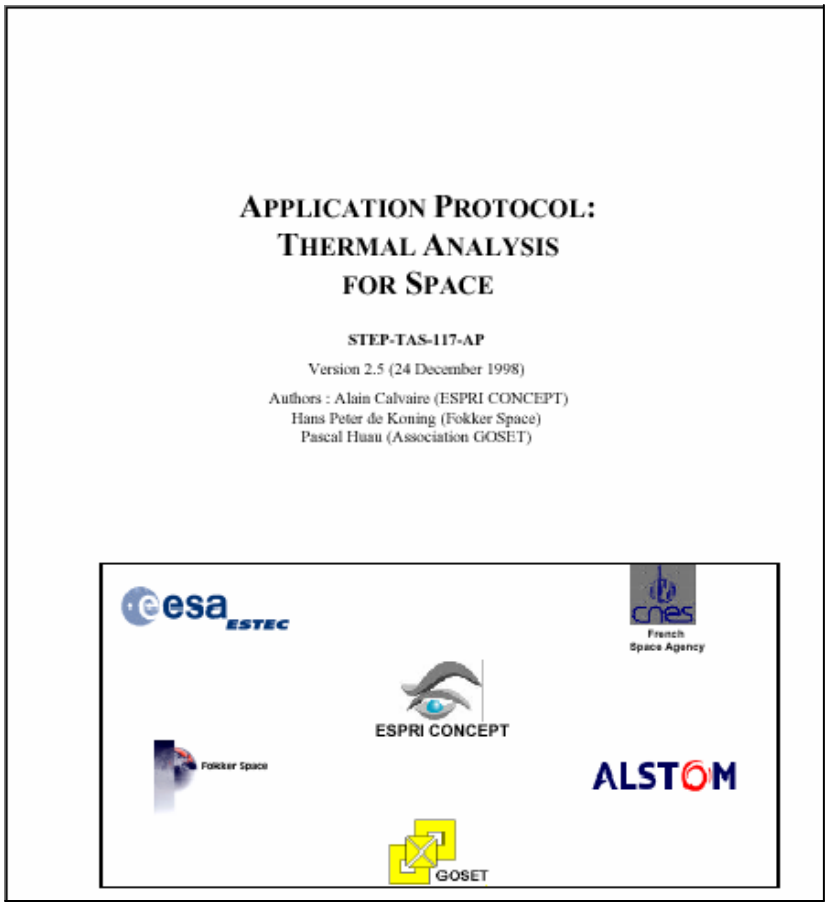
- STEP-TAS = STEP-Thermal Analysis for Space



Application Protocol for space missions and models used in thermal analysis.

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STEP-TAS Consists of Four Modules

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- NRF: Network-model and Results Format
  - Hierarchical model format, parametrics, materials and properties, cases, and results including test data
- MGM: Meshed Geometric Model
  - Meshed primitives including boolean operations, nested coordinate systems, compound shapes
- SKM: Space Kinematic Model
  - Rigid body kinematics with six degrees of freedom and end stops
- SMA: Space Mission Aspects
  - Pointing direction in space, Keplerian orbit arcs, articulation and tracking

U.S. Pilot Project 2000

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esa ESTEC

C&R Technologies®

Network Analysis SINDA/G

SpaceDesign

cnes

SIMULOG

TAC TECHNOLOGIES
Home of the NEVADA Software Package

HARVARD THERMAL
Thermal Modeling Software
Thermal Consulting and Engineering Services

STEP-TAS Pilot Demo
11th Thermal & Fluids Analysis Workshop
Glenn Research Center
Cleveland, Ohio
August 21-25, 2000

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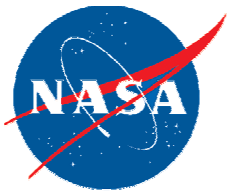
History



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- C&R began pilot project shortly after the first STEP-TAS spec was released in 1998, under funding from NASA
- The STEP-TAS development toolkit proved insufficient for full industrial use due to size and speed constraints
- In 2003 ESA began development of an EXPRESS STEP-TAS toolkit based on new approaches
- A subset of this new toolkit was implemented by C&R under a NASA Phase I SBIR contract NNC07QA79P
  - **Contracting Officer Melissa Merrill**
  - **Technical Representative Georg Siebes**

Motivation for Phase I

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- Spacecraft projects today consist of many different cooperating companies and institutions, typically using different thermal design and analysis tools
  - Even within a single organization, many tools are typically used
- Exchange of vital data is difficult, costly, or impossible
- Embracing an international data exchange standard satisfies data exchange needs as well as promoting competition and innovation, benefiting the end user

Phase I SBIR Results

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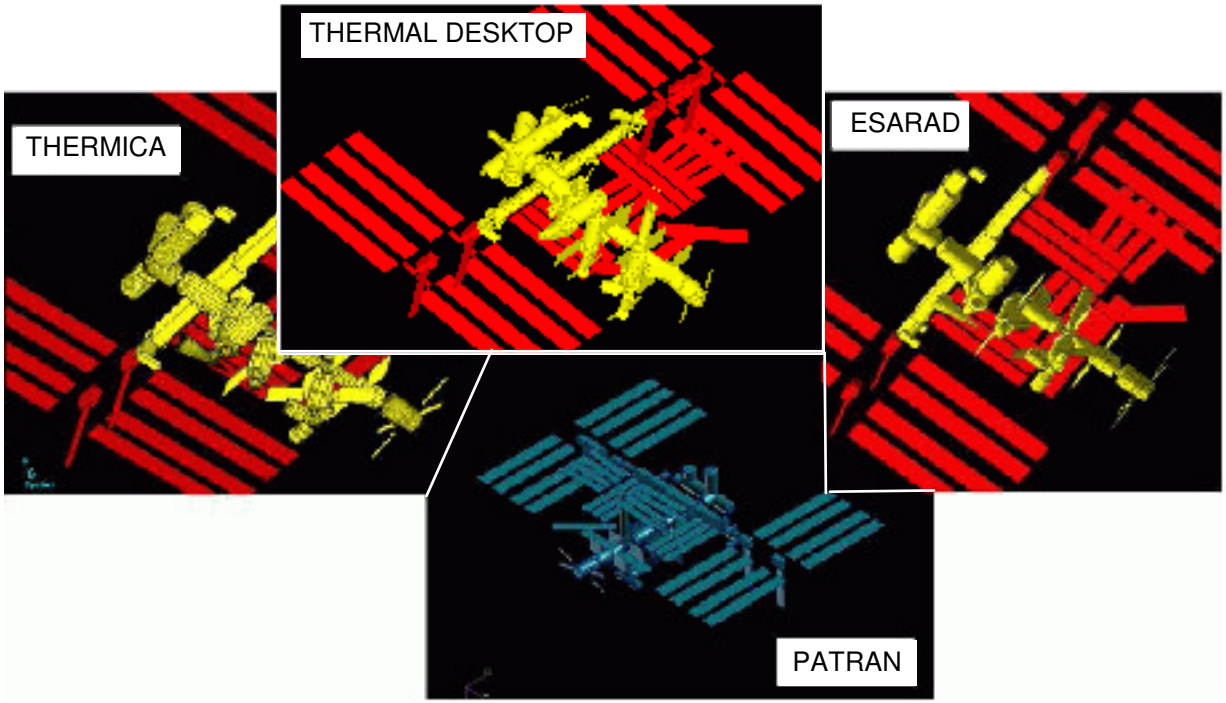
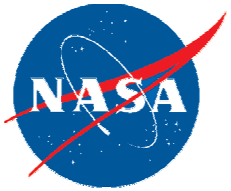


Figure 1: Facilitated Model Data Exchange

(Modified from "Deployment of STEP-TAS Thermal Model Exchange," Hans Peter de Koning, TFAWS 2006)

Scope of Phase I Effort



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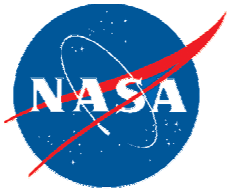
- Implement the capability within Thermal Desktop to create and accept STEP-TAS MGM data files
  - Optical properties
  - Only primitives and features common to both Thermal Desktop and STEP-TAS
- Demonstrate the utility on a number of test cases
  - Individual primitive test suite supplied by ESA
  - Space Station model
- Validate implementation approach and prepare plans for Phase II Effort

Getting Started



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- Modern data design methodology required getting up to speed on new technologies
  - Schemas and their specification using the EXPRESS language
  - Generating API's by binding the schemas to programming languages
  - Learning the STEP-TAS Application Reference Model (ARM)
    - Gone are the days of a simple column or keyword based file
- Initial trades were performed to select the best implementation approach
  - Call Python modules from Thermal Desktop
  - Export an intermediate file and use TasVerter
  - Implement using a C++ API

Python/TasVerter Approach

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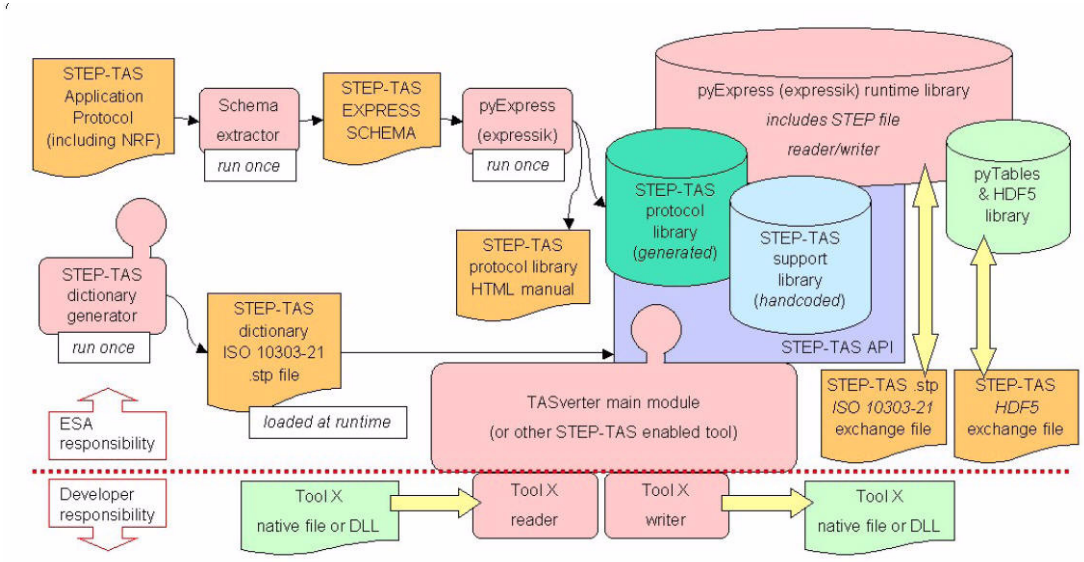
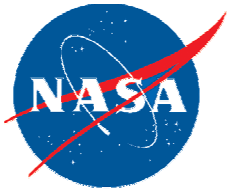


Figure 5: Architecture for Implementing STEP-TAS Converters

(Figure 2 from "Deployment of STEP-TAS Thermal Model Exchange," Hans Peter de Koning, TFAWS 2006)

- Proven and well documented
- Based on the Python programming language
- Initial plan of calling Python from C++ proved more difficult than anticipated
- An alternative intermediate file was considered, but that would have doubled the effort

C++ Toolkit Approach



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- Final choice was to use a C++ Toolkit provided by Centre Scientifique et Technique du Bâtiment (CSTB)
- Developed by CSTB under contract to ESA
- Based on Expressik, but a simpler interface
  - Size and speed improvements over Expressik
- Version 5.2 was used
  - Version 6.0 was released at end of contract period

Toolkit API Provides Classes to Match Entities in the ARM

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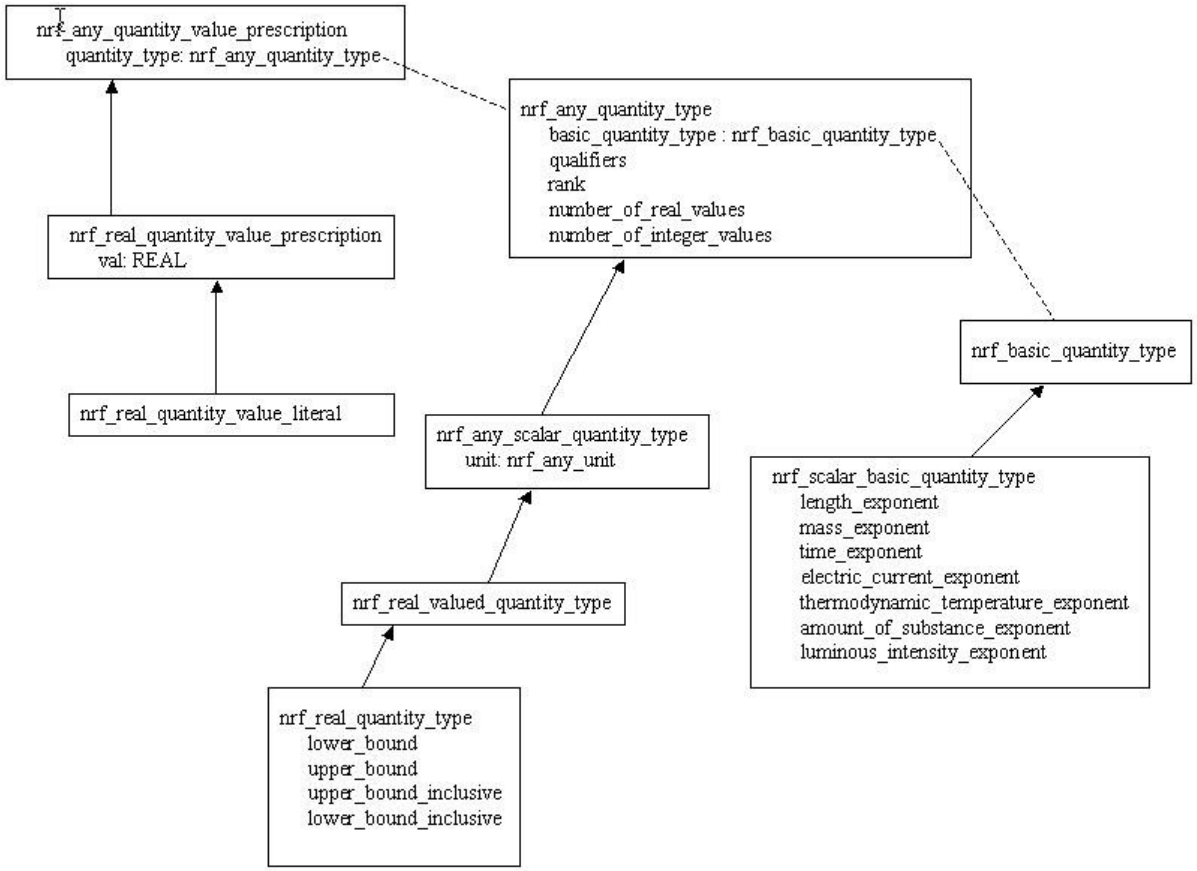

Additional Simplifying Layers Constructed

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<table>
<tr><td colspan="3">Thermal Desktop API</td></tr>
<tr><td>TD-to-Utility
Import Layer</td><td></td><td>TD-to-Utility
Export Layer</td></tr>
<tr><td colspan="3">Generic Utility Layer</td></tr>
<tr><td colspan="3">CSTB provided C++ STEP-TAS Toolkit</td></tr>
<tr><td colspan="3">STEP-TAS Application Resource Model
(EXPRESS)</td></tr>
</table>

Rigorous data design methodology is flexible, but complex

Additional layers were added to bridge the abstractions in Thermal Desktop with those in STEP-TAS

Generic Utility Layer is TD independent and can be used by other developers

Testing

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- Initially, the ASCII based part 21 file was visually compared against the ARM and example valid files
- Geometry verification was done by using CSTB's Baghera View
  - General purpose STEP viewer for TAS and AP203
- STEP files exported by TD were imported by TD
- STEP files exported by TD, converted to TRASYS models using TasVerter, then re-imported into TD

Verification Using Baghera View

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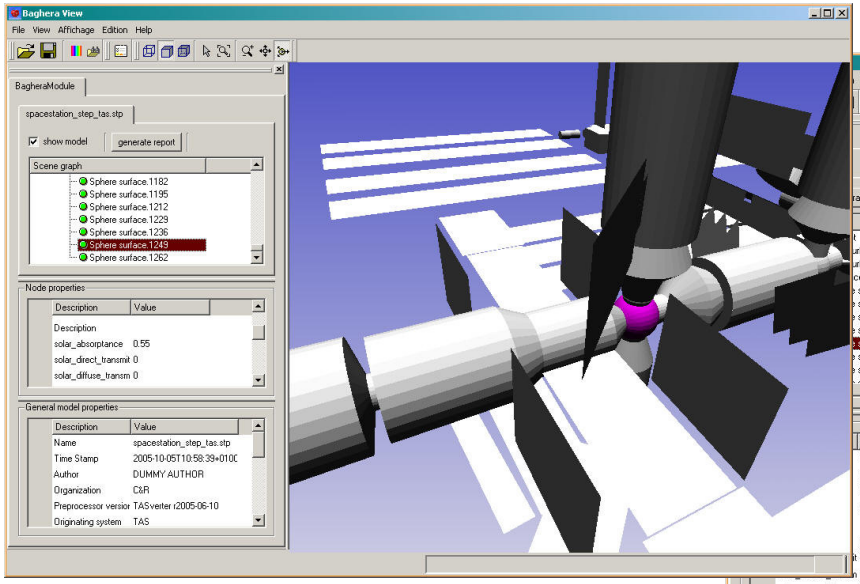
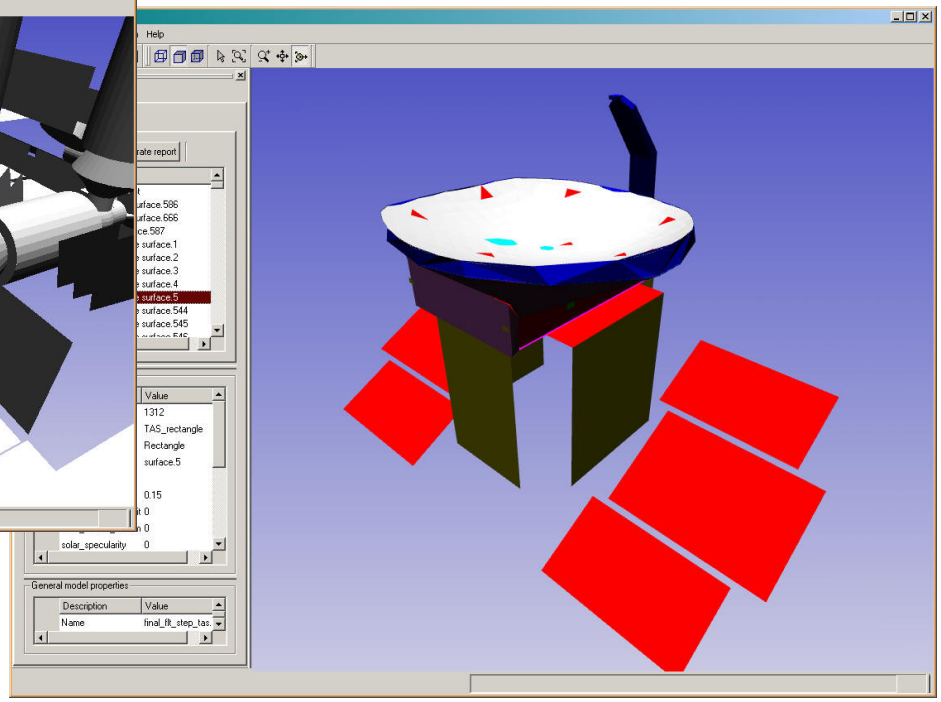
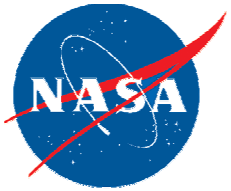


Space Station model from TD tutorial exported into STEP-TAS format and viewed with Baghera View



Cloudsat model provided by JPL

Results of Testing



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- Individual primitives have been tested
- Only a few "real world" models have been tested
- Implementation still considered "beta" until further testing with a wider variety of models is completed
- C&R welcomes and will assist any interested parties in translating test models

Using the STEP-TAS Importer/Exporter

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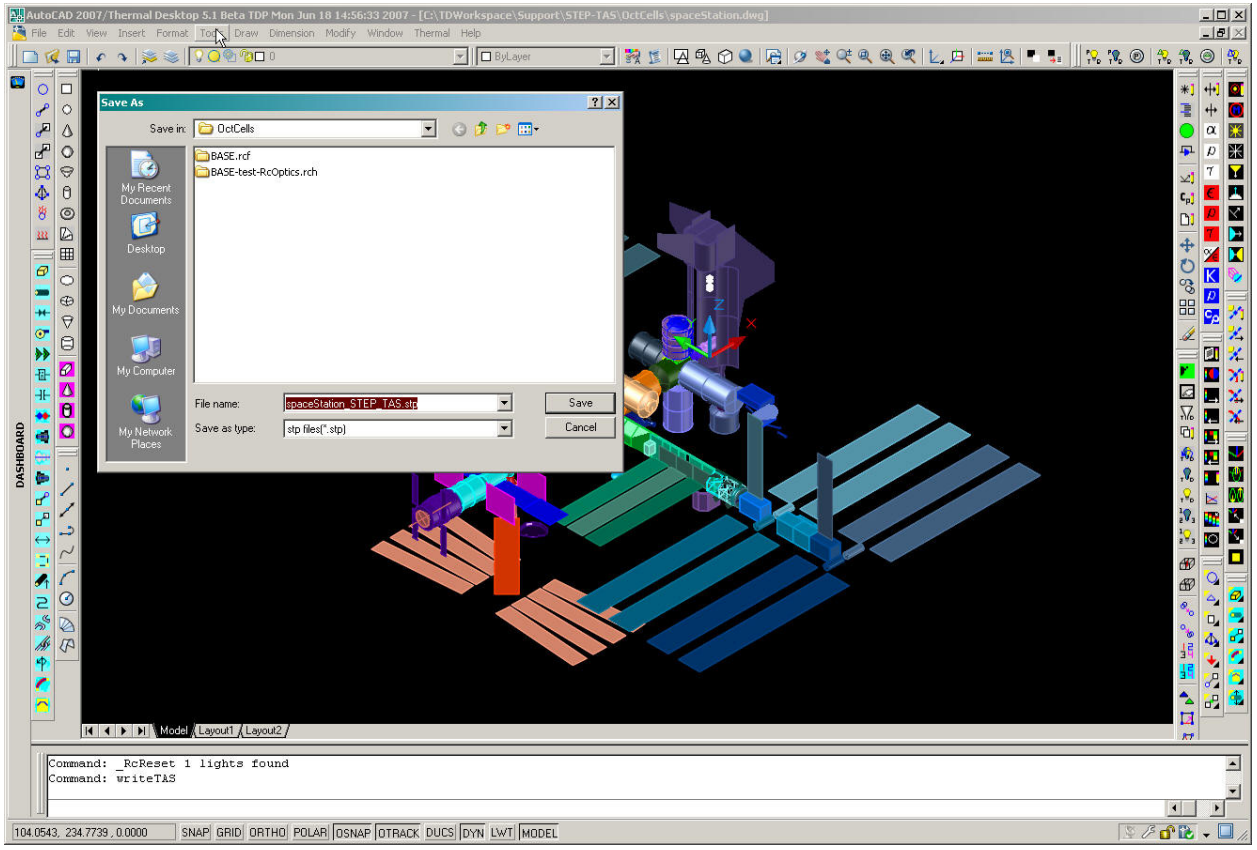
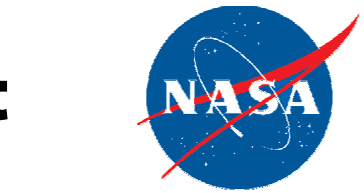


Available as a "lurker" in TD V5.1

commands:

- rcWriteTAS
- rcReadTAS

Future Plans Contingent Upon Phase II Start



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- Implement all four STEP-TAS modules using the most recent Version 6.0 of the protocol
  - NRF, MGM, SKM, and SMA
  - Interfaces will be present in Thermal Desktop, SINDA/FLUINT and SindaWorks
- Extend and modify Thermal Desktop to be compliant with the STEP-TAS standard
  - MGM extensions for primitives, optical properties, and booleans
- Provide new capabilities exploiting the features of the STEP-TAS protocol
  - NRF Data viewing and automatic model correlation to test data

STEP-TAS NRF

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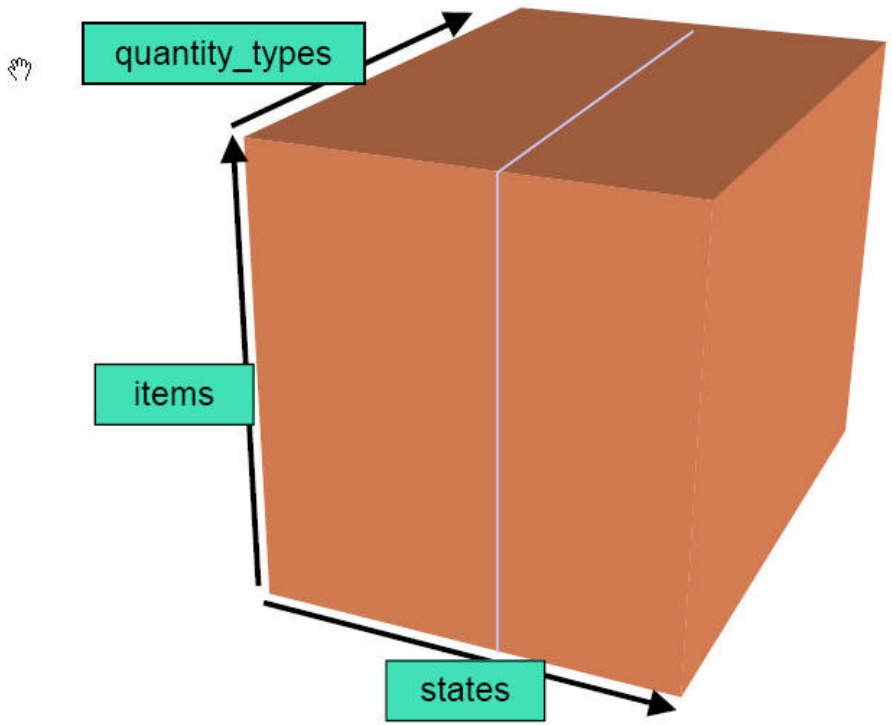

The STEP-TAS NRF "data cube" is a flexible architecture to store and retrieve results and test data

Sparse structure supported

In conjunction with HDF5, it will be a fast and efficient mechanism for archiving thermal data

Open, international standard will facilitate data transfer for thermal models as well as other to other applications for post processing and mapping to structural and optical models

NRF Data Viewer

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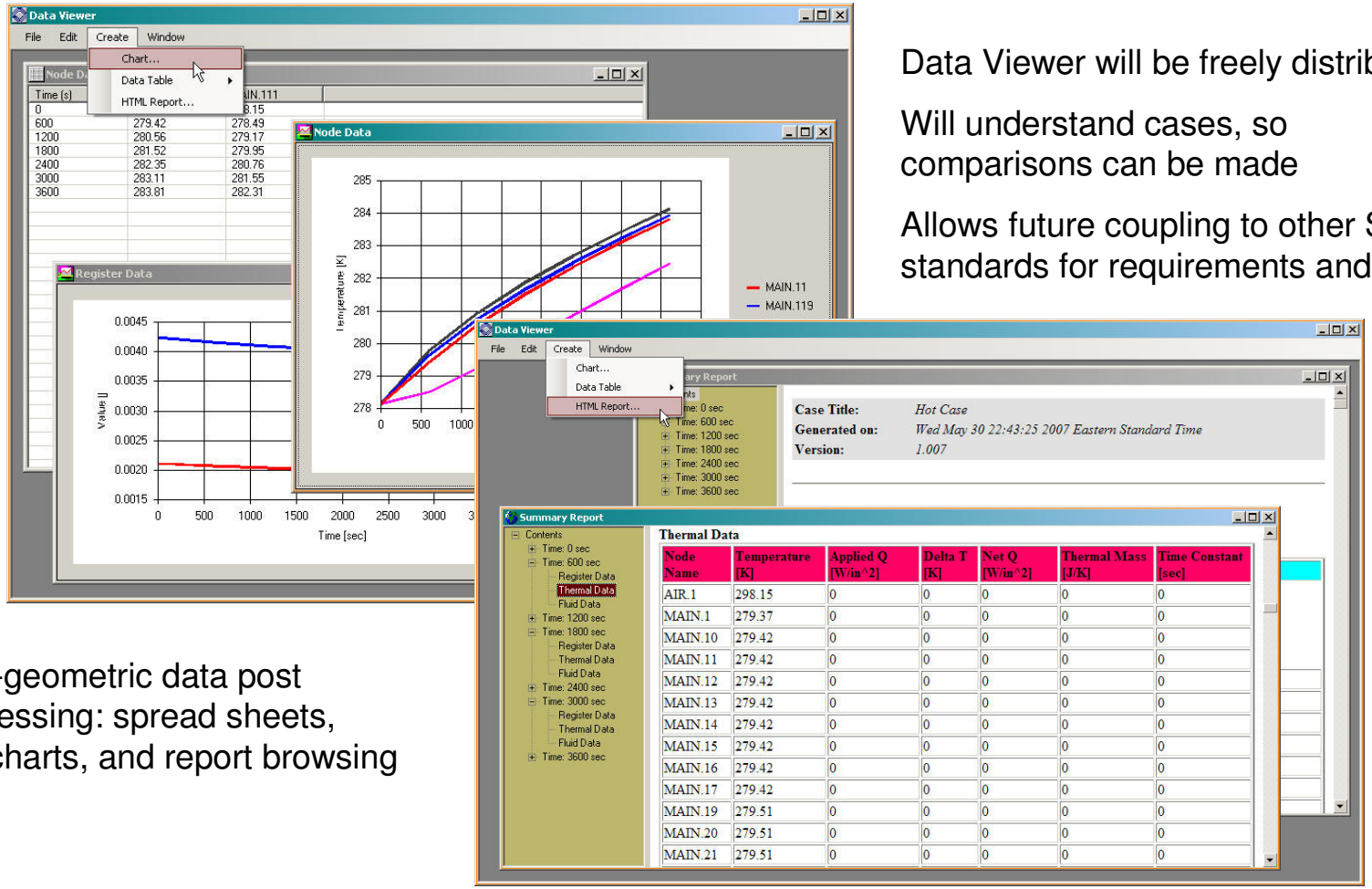

Node Name	Temperature [K]	Applied Q [W/in^2]	Delta T [K]	Net Q [W/in^2]	Thermal Mass [J/K]	Time Constant [sec]
AIR.1	298.15	0	0	0	0	0
MAIN.1	279.37	0	0	0	0	0
MAIN.10	279.42	0	0	0	0	0
MAIN.11	279.42	0	0	0	0	0
MAIN.12	279.42	0	0	0	0	0
MAIN.13	279.42	0	0	0	0	0
MAIN.14	279.42	0	0	0	0	0
MAIN.15	279.42	0	0	0	0	0
MAIN.16	279.42	0	0	0	0	0
MAIN.17	279.42	0	0	0	0	0
MAIN.19	279.51	0	0	0	0	0
MAIN.20	279.51	0	0	0	0	0
MAIN.21	279.51	0	0	0	0	0

Data Viewer will be freely distributable

Will understand cases, so comparisons can be made

Allows future coupling to other STEP standards for requirements and cost

Non-geometric data post processing: spread sheets, XY-charts, and report browsing

Automatic Data Correlation

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- Thermal test data is part of the NRF specification
  - If test organizations provide data in this format, automatic model correlation can be performed
- "Thermocouple" and other measuring objects will be implemented in Thermal Desktop
  - Placed in the thermal model at actual TC locations
  - Generates data for SINDA/FLUINT
- Since format of the test data is known, logic that computes a goodness of fit between predicted and measured data is generated automatically by TD
  - S/F Solver varies user defined parameters to achieve best fit
  - Many items can be correlated: temperature, heater duty cycle...

STEP-TAS MGM

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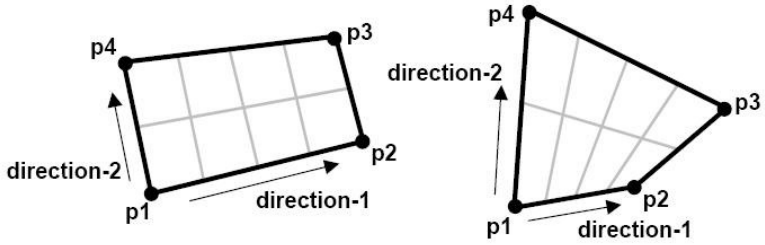
- STEP-TAS supports a few primitives and operations that are not supported in Thermal Desktop/RadCAD
  - Subdividable quadrilaterals and triangles

4.1.12.12 ENTITY tas_quadrilateral

A tas_quadrilateral is a type of tas_primitive_bounded_surface that specifies a planar quadrilateral surface bounded by four straight edges, defined by four points.



  - Boolean operations
  - Optical properties in STEP-TAS are also organized by "environment"
    - bol, eol, 5 year low earth, etc...
    - TD must use aliases or separate property files

STEP-TAS SKM

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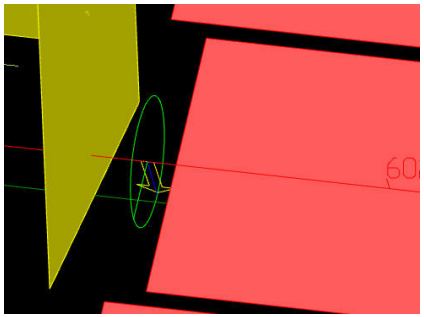
- The Space Kinematic Model protocol specifies:
  - Rigid body kinematics specified on MGM
    - Six degrees of freedom
    - End stops
  - Tracking of celestial bodies by articulating assemblies



- No standard currently exists for exchanging this kind of data among thermal tools

STEP-TAS SMA

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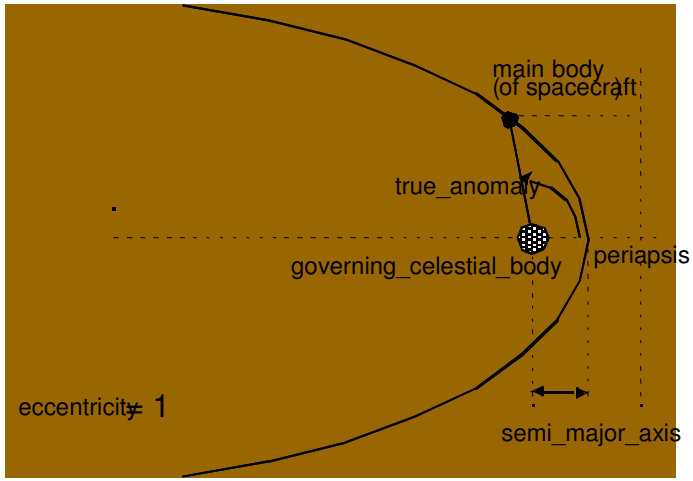
- Space Mission Analysis module specifies:
  - Space mission analysis case
    - chains of sub cases
    - events during the simulation
  - Space coordinate system
  - Pointing direction in space
  - Orbit arcs
    - Keplerian or general ephemeris
  - Celestial body



- Export/Import of SMA/SKM/MGM data will benefit TD-to-TD transfer as well as between different tools
  - All-in-one package

Summary

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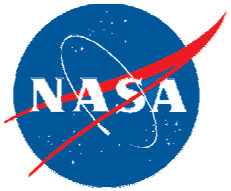
- Open standards encourage competition and innovation, proprietary barriers don't - STEP-TAS satisfies model exchange requirements
- A subset of STEP-TAS Version 5.2 MGM has been implemented in Thermal Desktop under a Phase I SBIR
  - Available in Thermal Desktop 5.1 (beta downloadable)
- Phase II plans (if awarded)
  - Complete implementation of remaining STEP-TAS modules
    - Version 6 MGM, NRF, SMK, and SMA
  - Extend Thermal Desktop to be fully compliant with protocol
    - Boolean operations, additional primitives, redesigned property databases
  - Implement innovative features made possible by the protocol
    - Data viewer, automatic correlation

Acknowledgement



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- We do want to acknowledge Hans Peter de Koning from ESA/ESTEC, who was absolutely instrumental to the STEP-TAS development and provided essential support during this implementation

- Also a special thanks to Eric Lebegue and Elisa Ciuti of CSTB for their support and for providing examples supplied with the C++ toolkit

Q&A

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Thank You!

… Any Questions?

Backup Material

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- A good summary of STEP APs can be found at http://en.wikipedia.org/wiki/ISO_10303

- TAS-Verter (free thermal geometric model converter based on STEP-TAS) at https://exchange.esa.int/restricted/tasverter/

- Baghera View (free thermal geometric model and solid model viewer based on STEP-TAS) and AP203/214 at

  http://salle-immersive.cstb.fr/en/webzine/preview.asp?main=18&id_une=33