Conference and Exhibition of the European Association of Virtual and Augmented Reality (2014)
G. Zachmann, J. Perret, and A. Amditis (Editors)

Virtual Reality Interface for Multidisciplinary Physical Analysis of Space Vehicles

Agata Marta Soccini[1], Manuela Marello[3],
Nello Balossino[1], Christian Bar[3], Valter Basso[2], Maurizio Lucenteforte[1], Daniele Perlo[1], Filippo Racca[4], Lorenzo Rocci[2]

[1] Department of Computer Science, University of Torino, Torino, Italy
[2] Thales Alenia Space Italia, Torino, Italy
[3]SSE-SOFITER SYSTEM ENGINEERING S.p.A, Torino, Italy
[4]ORTEC Innovazione e Tecnologia S.R.L., Torino, Italy

Abstract

Physical analysis of Space Vehicles during the pre-launch phase is often performed using mono or multi-disciplinary software tools developed for the specific research intent. The mentioned tools, their methods and their results are seldom accessible and rarely deeply understandable outside the single research groups.

This paper presents a solution based on a new technical and interaction design. We encourage to interface Virtual Reality 3D systems with the tools that perform the quantitative physical analysis of given space vehicles, as this approach improves productivity and communication effectiveness and brings consisting benefits to the engineering and design collaborative processes.

We report an evaluation of this method based on the implementation of the mentioned system at the Collaborative System Engineering center at Thales Alenia Space in Torino, Italy, as part of the project STEPS2.

This evaluation showed that users found the Virtual Reality interface easy to use and likely to be useful in their own work.

Category and Subject Descriptors: I.3.7 [Computer Graphics]: Virtual Reality – Three-Dimensional Graphics and Realism

1. Introduction

In space exploration, pre-launch tests on vehicles form a critical, delicate and very expensive phase. They are a core resource for analyzing eventually discriminative situations and retrieving data regarding the physical behavior of the craft in definite environments. These data are fundamental for all the disciplines involved in the design and engineering of the vehicles themselves and their mission, and their calculation is performed using software for quantitative analysis of astrophysical simulations.

Research groups at Space Agencies and specialized Enterprises often need to design and develop in house software tools to perform disparate physical analyses. Most of the time the tools are not shared outside the group, and the results reached by each group is rarely immediate for outsiders.

This organization leads to the occurrence of anomalies in the communication and collaboration process, as well as difficulties or inhibition in the interpretation and management of complex big amounts of data.

While data analysis and visualization toolkits not only exist, but also work with several astrophysical simulation codes and can be used as common platforms for multidisciplinary analysis [TSO*11], we suggest a light, ergonomic and fast technologic improvement that we believe can be complementary and integrative to the mentioned approach. We give the tools an ergonomic real-time three-dimensional Virtual Reality interface that not only provides a better and clearer visualization, but also guarantees an easy and immediate interactivity with the system [Wan11].

Users can model the several different combinations of environments and assets they want to test, and visualize the physical behavior of the vehicle in those specified situations.

Even though the concepts of Virtual Reality benefits in space simulations are not new [WQ10], we believe that applying Virtual Reality methods to the physical analysis - and therefore interface a three dimensional Virtual Reality systems with physical analysis tools- gives extra value to opportunities and experiences of communications and tests, increasing collaboration, organization and productivity, and above all gives a smart interactive visual easy and real time access not only to results but to tools themselves.

Scientists and engineers can analyze heterogeneous, complex, mono or multimodal data in a short time and in a visual way, whatever their background is, and ignoring the inner behavior and the original interface of the tool.

DOI: 10.2312/eurovr.20141330

Quick and evident tests can be done to verify and independently validate results of researches, taking advantage of an eased way to model the environment and the asset [Wan11].

By sharing the results of our research, we hope not only to encourage the use of Virtual Reality as a strong Collaborative Engineering support for sharing the results of the analysis among the research groups, but also to promote it as a way to give access to outsiders to processes, results and tools of specific analysis, in order to simplify and increase overall views.

2. Technologies and Project Overview

As part of the project STEPS2 [web*ST2] at Thales Alenia Space Italia [web*TAS], in Torino, in the Technology Research Group at COSE (COllaborative System Engineering Centre) [PBR*11], we designed and implemented the interaction and interface of a Virtual Reality 3D system mainly intended to simulate space exploration, with software that calculates specific thermodynamic quantities of a given spacecraft in a given environment.

STEPS2 is the Italian acronym of Systems and Technologies for Space Exploration (Sistemi e Tecnologie per l'EsPlorazione Spaziale) and is the second part of STEPS [PMG*11], a research project whose goal is the development of new technologies for planet exploration. The project involves public administrations, industrial and academic partners, including University of Torino and Thales Alenia Space Italia [PBM*12].

We used IXV data as model of space vehicle [web*IXE], VERITAS -initially known as TraVis, TRAjectory VISualizer- [BMF08] as Virtual Reality system, ATDB Tool for the thermodynamic analysis.

Let’s start with the spacecraft: IXV –Intermediate eXperimental Vehicle- is a European Space Agency (ESA) [web*ESA] experimental re-entry vehicle intended to validate, among others, the predictive models used to design the vehicle, i.e. fluid dynamics, thermodynamics, fluid-thermodynamics. The design finalization, in terms of tests and integration, of IXV has been entirely assigned to the offices in Torino of Thales Alenia Space [web*IXT].

The core technology is a three-dimensional (3D) Virtual Reality system, called VERITAS (Virtual Environment Research In Thales Alenia Space).

VERITAS is a framework that includes several different Virtual Reality applications, designed to run either in a CAVE with up to six screens, or on a desktop computer.

It is property of Thales Alenia Space Italia, and has been developed at COSE since 2004 with the original name of TraVis, as It was first designed only to visualize space vehicles and their trajectories [MB08]. In order to be more flexible and adaptable to meet new needs and support new case studies regarding space missions, the Solar System, the International Space Station (ISS), or detailed terrains of Mars and the Moon [web*TER], TraVis was extended during the years, and took the name of VERITAS.

ATDB Tool, acronym of Aero-Thermo-Dynamic Data Base Tool is an aerothermodynamics analysis tool specifically designed and developed for IXV [MFZ*11].

It takes as input a model of the environment -in terms of Mach, Temperature, Pressure, Density- and an asset –in terms of Elevon, Aileron, Sideslip, Attack-, and returns as output a punctual aerothermodynamics analysis.

In Figure1, we can see the VERITAS Simulation Options Panel that let users set the mentioned quantities.

The two systems, VERITAS and ATDB Tool, can both represent and understand, using dramatically different approaches, the geometry of a spacecraft.

While VERITAS can represent and nicely visualize a wide set of standardized geometries, and is able to simulate their behavior and interaction with other space objects, ATDB Tool has old style basic low level interfaces and only works with IXV data, but, given an asset and an environment, can calculate some thermodynamic quantities (i.e. pressure, temperature) of the vertices of the represented geometry that VERITAS does not originally consider.

The interaction between the two systems became the natural perfect use case to implement the technologies and therefore validate the theories we are discussing.

In Figure2 we see the Right Flap of IXV visualized in VERITAS after an interaction with ATDB Tool.

3. Implementation and validation

We added to VERITAS a class, called ATDBStillViewer, written in C++ and based on OpenSG libraries [web*OSG].

ATDBStillViewer conceptually let us visualize in a Virtual Reality environment specific aero-thermodynamic quantities of IXV that are not visible in real world. As previously specified, the predictive calculations are performed by ATDB Tool.

While the input of ATDB Tool can be sent via command line on a Linux shell, as well as written on a text file, the output is coded in Tecplot files [web*TEC].

As mentioned before, our core research does not consist in the development of innovative visualization algorithms, but in the design of new uses of interfaces and ergonomic collaborative experiences [Wan11]. That’s why we choose to proceed with the description of the interaction design and not of the code itself.

1. First of all Users can load a scene with a IXV tree in VERITAS, access the ATDBStillViewer call button in the menu, and open the form that let them define the asset and the environment they want to test.
2. Once set the parameters, users call ATDB Tool, and, in an approximate real time, the Tecplot fileappears in the scene. This can be done several times, and every time a new Tecplot appears. We can

see in the Scene Tree View how every call creates a new Tecplot subTree in the scene tree. Every Tecplot hierarchy is a brother of the actual visualized geometry.

3. This interface also lets us check the original parameters users set to calculate the punctual thermodynamic quantities. In the ‘pick one Tecplot’ list users can select one of the Tecplot files in the scene and see their original values.

4. Once seen the original parameters, users can change from one to all of them to get a new simulation. All changed parameters are marked in lime green.

5. Feel free to loop from point 2, or enjoy the results of your analysis

As the system visualizes the spacecraft and the Tecplot files, users can interact with the 3D space with all the functionalities provided by VERITAS.

Figure3 and Figure4 show a visualization in VERITAS of the Spacecraft with two Tecplot beside. Not only this ergonomic interaction, but also theses immediate visual results would not be possible without our new Virtual Reality Interface for Multidisciplinary Physical Analysis Tools.

4. Summary

The representation of non-visible physical quantities in a Virtual Reality system, together with an interface to physical analysis tools, can be considered a core feature for an actual implementation of collaborative engineering methodologies.

We received enthusiastic feedback by other Working Packages of STEPS2, as well as by Engineers and Scientists at Thales Alenia Space.

As a proof of the enthusiasm, we can mention the will of the research groups of STEPS2 to use this approach as a standard technology for the next vehicles that will be assigned to the partners involved in the project. An ambitious and exciting project that we hope will start soon.

The described results also confirm the interest and the efforts of Thales Alenia Space Italia -and of the COSE Centre in particular- towards the advantages of Collaborative Engineering, Model Based System Engineering and Virtual Reality.

The suggested approach to aero-thermal analysis will be therefore applied to other disciplines in a more organic context, taking advantage of methodologies related to Collaborative Engineering and Model Based System Engineering.

5. References

[BMF08] CHRISTIAN BAR, MANUELA MARELLO, ATTILIO FERRARI:
TraVis -- A Virtual Reality Interactive Application For Scientific And Aerospace Visualization And Simulation.
Proceedings of the 19th International Planetarium Society Conference, Chicago, USA, 2008.
http://c.ymcdn.com/sites/www.ips-planetarium.org/resource/resmgr/pdf-conf/2008_proc_chicago.pdf

[MB08] M.MARELLO, C.BAR:
TraVis - A Virtual Reality Application For Interactive Simulations In Aerospace And Astronomy.
5th INTUITION International Conference, Turin, Italy, 2008

[MFZ*11] V.MARESCHI, D.FERRARELLA, E.ZACCAGNINO, J.P.TRIBOT, J.J.VALLEE, R.HAYA-RAMOS, G.RUFOLO, S.MANCUSO:
INTERMEDIATE EXPERIMENTAL VEHICLE, ESA PROGRAM IXV ATDB TOOL AND AEROTHERMODYNAMIC CHARACTERIZATION.
7th European Symposium on Aerothermodynamics for Space Vehicles. Brugge, May 9 - 12, 2011.
http://esamultimedia.esa.int/multimedia/publications/SP-692/SP-692-toc.pdf

[PBM*12] M.PASQUINELLI, V.BASSO, M.MARELLO, C.PACCAGNINI:
STEPS Results: MBSE Prototypes to support Space Exploration Projects Lifecycle.
5th International Workshop on System & Concurrent Engineering for Space Applications, Lisbon, Portugal, 2012

[PBR*11] M.PASQUINELLI, V.BASSO, L.ROCCI, C.BAR, M.MARELLO, L.PIOVANO, D.RIPOSATI, C.VIZZI, F.BECHERINI, M.CENCETTI:
COSE CENTRE: SYSTEM MODELLING AND HUMAN VIRTUAL MODEL INTERACTION TO SUPPORT THE FUTURE MANNED EXPLORATION PROJECTS.
62nd International Astronautical Congress 2011 (IAC 2011). Cape Town, South Africa, 3-7 October 2011
IAC-11-V,3,4,x12139

[PMG*11] M.A.PERINO, P.MESSIDORO, E.GAIA, D.BOGGIATTO:
STEPS PROJECT – TECHNOLOGIES AND SYSTEMS FOR SPACE EXPLORATION.
62nd International Astronautical Congress 2011 (IAC 2011). Cape Town, South Africa, 3-7 October 2011
IAC-11-D3.2.2

[TSO*11] MATTHEW J. TURK, BRITTON D. SMITH, JEFFREY S. OISHI, STEPHEN SKORY, SAMUEL W. SKILLMAN, TOM ABEL AND MICHAEL L. NORMAN:
yt: A MULTI-CODE ANALYSIS TOOLKIT FOR ASTROPHYSICAL SIMULATION DATA. *The Astrophysical Journal Supplement Series*, 192:9, 2011 January.
doi:10.1088/0067-0049/192/1/9

[Wan11] WANG JIN: Virtual Reality Technology in the Design of the Space Environment Research *Control, Automation and Systems Engineering (CASE), 2011 International Conference on*
IEEE CONFERENCE PUBLICATIONS
doi:10.1109/ICCASE.2011.5997892

[WQ10] WEN YUEJIE, LI QIANG:
Virtual Spacecraft Design: An Effective Training Method.
61st International Astronautical Congress, Prague, CZ, 2010.
IAC-10-E1.4.14

[web*ESA] European Space Agency, website:
https://www.esa.int

[web*IXE] IXV at European Space Agency, website:
http://www.esa.int/Our_Activities/Launchers/IXV

[web*IXT] IXV at Thales Alenia Space in Turin, Finmeccanica website:
http://www.finmeccanica.com/-/ixv

[web*OSG] OpenSG, website:
http://www.opensg.org

[web*ST2] Phase 2 of STEPS Program, Thales Alenia Space Press Release, Thales Group, website:
https://www.thalesgroup.com/sites/default/files/asset/document/pr_STEPS_21032013_EN.pdf

[web*TAS] Thales Alenia Space, website:
https://www.thalesgroup.com/en/homepage/italy

[web*TEC] Tecplot, website:
http://www.tecplot.com/

[web*TER] STUDIO DI RICOSTRUZIONE TRIDIMENSIONALE DI SUPERFICI PLANETARIE E LORO PROTOTIPAZIONE PER UN AMBIENTE DI REALTAVIRTUALE.
Master's Thesis by Agata Marta Soccini:
https://drive.google.com/file/d/0Bz15-5ZTF0-yb0lVNXdMQWtXQk8teXh4Rm9iaXR1MzhPZ1FJ/view?usp=sharing

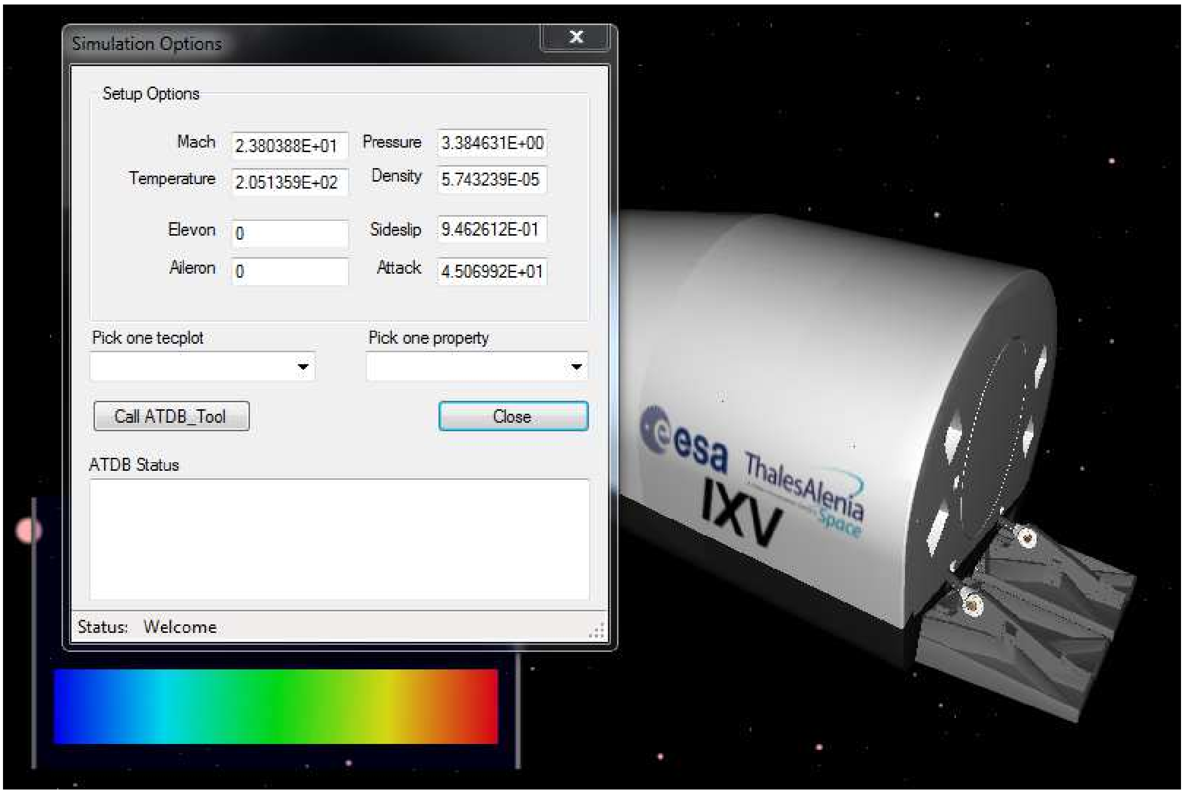

Figure 1: *The VERITAS interface users fill in order to model the environment for which they want to perform the thermodynamic analysis.*

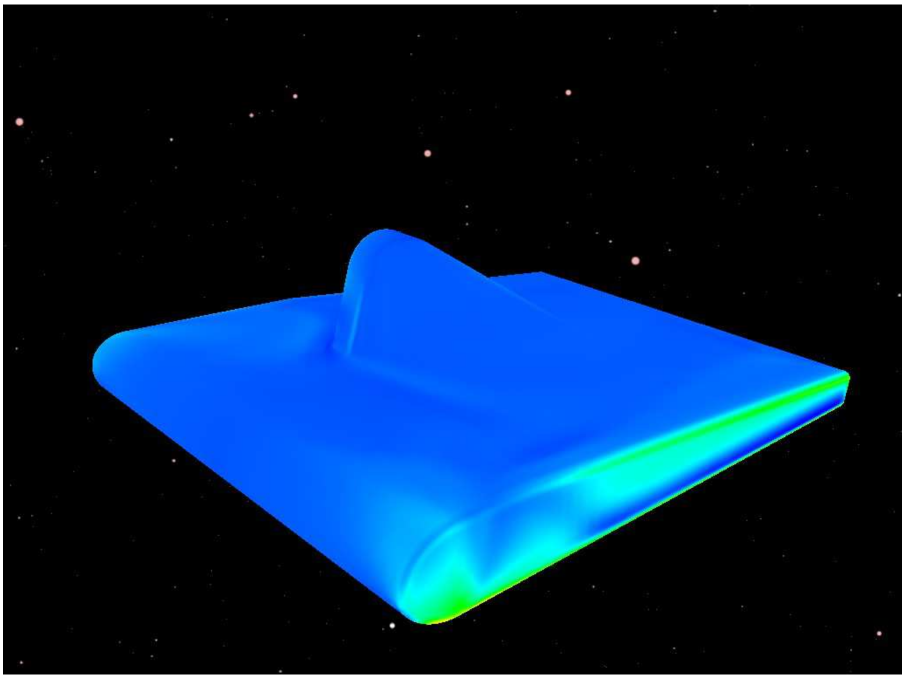

Figure 2: *A visualization of the right flap of IXV, colored according to the results of the thermodynamic analysis*

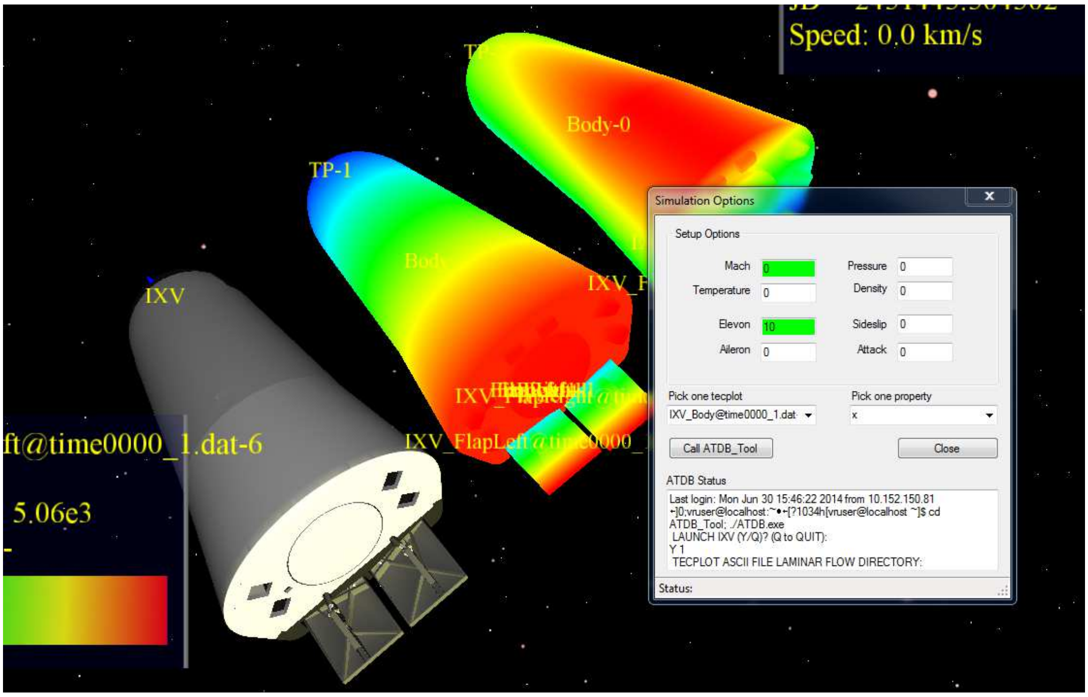

Figure 3: *A basic output of two calls to ATDB Tool through VERITAS. In this figure we show the X and Y values of IXV in the three-dimensional space, just to focus on the visualization of the vehicle with a colored and easily understandable map*

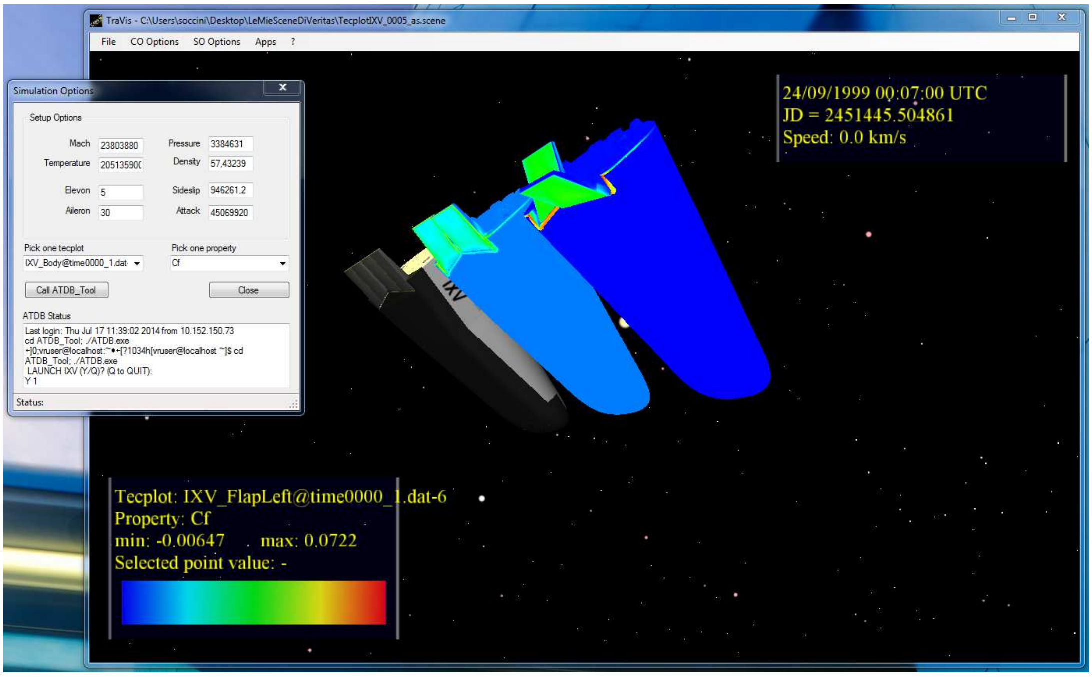

Figure 4: *In this figure we see the output of two different calls to ATDB Tool through VERITAS. We focus not only on the meaningful colored output of the process, but also on the rotation of the flaps, that has been set by the users in terms of Elevon and Aileron using the form shown in Figure1.*