

Framework Concept for Satellite Operations

Miguel Angel Molina, Jose Prieto

GMV – c/ Isaac Newton, 11
PTM Tres Cantos
28760 Madrid
SPAIN

Tel: +34 918072100; Fax: +34 918072199

mamc@gmv.es, jjpm@gmv.es

Gonzalo Garcia, Theresa Beech

GMV Space Systems
1 Research Ct, Suite 450
Rockville, MD 20850
USA

Tel: +1 301 216 3840; Fax: +1 301 519 8001

US_marketing@gmvspacesystems.com

ABSTRACT

GMV has developed an internal project, called *FOCUS*, to produce a new generation multi-satellite and multi-mission framework. Project *FOCUS* came through successful requirements definition during the first half of 1999 and the development phase started in August 1999. *FOCUS* has very ambitious goals in mind, in particular the development of a truly generic operational framework for all types of satellite missions (including GEO, LEOP, LEO, satellite formations, constellations, etc.) to be commercialised as a COTS product. This led in the last few years to *FOCUSSuite*, a suite of operational products that cover all these types of missions.

1.0 INTRODUCTION

The design of new satellite control systems is driven by the imperative need to reuse legacy software, exhaustively exploited during years of operations which have qualified them as “flight proven”, and the desire to use modern software technologies which dramatically boost system usability, accessibility and stability. In order to fulfill those objectives, the “framework” concept appears as the required support for future on-ground satellite systems development.

Framework concept is thus oriented to minimize program development schedule, costs and risks, and at the same time to improve the efficiency of operations (minimizing operations workload) and reducing the risk of human errors. In order to meet these ambitious goals, the framework should provide a number of ready to use components for data manipulation and visualization as well as event logging, overall framework architecture, communications layers, process management, automation and reporting. Nevertheless, the real power behind the framework lies in its ability to integrate external components. While the integration of disparate software is usually a hard task plagued with difficulties (programs not conceived to act as components, wealth of protocols and formats, unclear interfaces, etc.), a framework makes this issue straightforward. The framework should also provide well-designed, high performance, robust, customizable, extensible, flexible and *coherent* Graphical User Interfaces (GUIs), promoting graphical views as much as possible.

Such a framework would allow integration of flight dynamics algorithms with unprecedented ease. Those flight dynamics functions may come from different origins in terms of programming language. Interface between the framework and the flight dynamics algorithms should be based on the implementation of an API (Application Programming Interface) in order to manage the processing and the data interfaces. Management of new entities (e.g. satellites) in the system should be performed by simply modifying editable configuration files. Those configuration files can be interpreted by the framework system in order

Angel Molina, M.; Prieto, J.; Garcia, G.; Beech, T. (2005) Framework Concept for Satellite Operations. In *Integration of Space-Based Assets within Full Spectrum Operations* (pp. 10-1 – 10-12). Meeting Proceedings RTO-MP-SCI-150, Paper 10. Neuilly-sur-Seine, France: RTO. Available from: <http://www.rto.nato.int/abstracts.asp>.

Report Documentation Page

Form Approved
OMB No. 0704-0188

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE 01 AUG 2006	2. REPORT TYPE N/A	3. DATES COVERED -			
4. TITLE AND SUBTITLE Framework Concept for Satellite Operations		5a. CONTRACT NUMBER			
		5b. GRANT NUMBER			
		5c. PROGRAM ELEMENT NUMBER			
6. AUTHOR(S)		5d. PROJECT NUMBER			
		5e. TASK NUMBER			
		5f. WORK UNIT NUMBER			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) GMV c/ Isaac Newton, 11 PTM Tres Cantos 28760 Madrid SPAIN		8. PERFORMING ORGANIZATION REPORT NUMBER			
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)			
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)			
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release, distribution unlimited					
13. SUPPLEMENTARY NOTES See also ADM202138, Integration of Space-Based Assets within Full Spectrum Operations (Integration des moyens spatiaux dans toute la gamme des operations., The original document contains color images.					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT UU	18. NUMBER OF PAGES 49	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

Framework Concept for Satellite Operations

to create the required database structure, to construct the overall GUI and to generate the required functionality including additional (if needed) generic functions like plotting or data acquisition and pre-processing. The issue of users and privileges needs also to be managed by the framework, in addition to automation which deserves special attention.

focusSuite includes a suite of **generic operational satellite control** systems (initially devoted to Flight Dynamics activities) sharing the same architecture and many common components. Each of them has a different computational layer, all of them based originally on flight proven ESA's packages like PEPSOC, NAPEOS and LEOPOLD. The following stand-alone **products** are included within focusSuite:

focusGEO is targeted to Geostationary satellites (see later on this paper).

- focusLEOP is a complement to focusGEO providing support for the Launch and Early Orbit Phase for geostationary satellites
- focusLEO is targeted to Low Earth Orbit satellites
- focusCⁿ is targeted to satellite constellations
- focusPlanet is targeted for interplanetary missions
- focusReentry is targeted for re-entry missions
- focusRdV is targeted for rendez-vous and formation flying missions

2.0 DESIGN DRIVERS

The following paragraphs describe at a high level functionalities of focusSuite which are common for all the members of the focus families:

- A **computation and data layer** based on the extensive reuse of existing and improved software. A large variety of satellite platforms in different orbit conditions (e.g. GEO, LEO, MEO, constellation, reentry, interplanetary, formation flying, etc.)
- A **client/server architecture**: All data and functionalities reside on a server which is accessed via a client GUI. Communications between client and server are done via TCP/IP. The possibility to work over the Internet with the appropriate degree of security has been foreseen.
- **Database driven**: All important mission data is stored in a database residing on the server side. The possibility to plug a commercial RDBMS like ORACLE into focus has been foreseen, although this is not mandatory being a proprietary database by default.
- An **advanced GUI**: The GUI integrates advanced widgets and a design philosophy based on commercial desktop applications for the office: "everything-in-one-working-area" and "all-one-click-away" (tabs). The GUI implementation is based on a proprietary toolkit called Tkforms that allows a development through configuration files rather than through code.
- Procedures automation capability through the AutoFOCUS extension, which is able to produce an automatic sequence and execution of modules required to fulfill a particular procedure. This automation is based on a dedicated language: SOL (Spacecraft Operations Language) also developed and integrated by GMV.
- Advanced **graphical capabilities**: Dedicated widgets for generic X-Y plots and Events visualization have been developed for focusSuite.
- **On-line help**: Complete User Manual available on-line in PDF format, with hypertext and navigation capabilities.

- **Portability (UNIX/Windows NT):** Both the client and the server part run under UNIX and Windows-NT. Any combination of the two operating systems is possible (UNIX/UNIX, UNIX/Windows-NT, Windows-NT/Windows-NT, Windows-NT/UNIX). Virtually all flavours of UNIX are supported, including Linux. At the client side any of Windows 95/98/2000/NT/XP are also supported.
- **Extensibility:** Any extra functionality following certain I/O rules can be easily integrated within focusSuite via configuration files. A server Interface Description and a graphical Server Manager are available.
- Capability to perform **unlimited Undo/Redo** operations: Any data editing and function execution operation can be undone and redone an unlimited number of times. This allows a quick and user-friendly operating of the product while maintaining at the same time the user confidence and the data integrity.
- **No licenses** of external products are required.

3.0 ARCHITECTURE

focusSuite is a database-driven framework, built as a three-layer architecture (GUI Layer/Computation Layer/Data Layer). Focus is also conceived as a client-server system, where multiple clients may be accessing concurrently the same server and database.

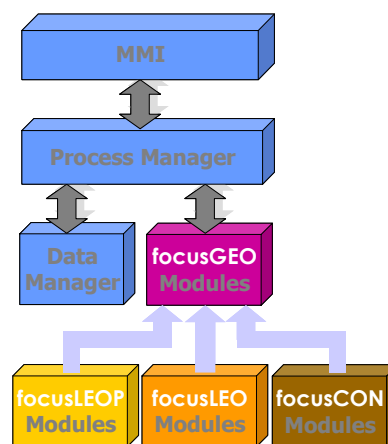


Figure 1 focusSuite Components.

focusSuite integrates many common components shared across the suite:

- GUI
- Events Logging
- Automation
- Process Management
- Data Management

A **client/server architecture** is considered as baseline for data transmission. All data and functionalities reside on a server which is accessed via a client GUI. Communications between client and server are done via TCP/IP. The possibility to work over the Internet with the appropriate degree of security has been foreseen.

Framework Concept for Satellite Operations

The **Computation Layer** is the bridge between user and data services. It responds to requests from the user (or other computation processes) in order to execute a process. This protocol insulates the user from direct interaction with the database. Two different types of processes are included in this layer:

- The Process Manager is a single process, receiving requests from the clients and starting and controlling the computation processes.
- The Computation Processes are multiple processes that can run concurrently and perform the computations needed by the system.

The **computation and data layer** are based on the extensive reuse of existing and improved software (e.g. PEPSOC, NAPEOS). The **Data Layer** maintains, accesses, and updates data. It also manages and satisfies requests to manipulate data that are initiated by computation processes. Separation of data services allows the data structure and access mechanisms to be maintained, modified, or, if necessary, even redesigned without affecting the computation or user layer.

Two different single processes running permanently can be identified in this layer:

- The **Database API Back-end** handles all the requests received from the computation processes.
- The Relational database (RDBMS).

All important mission data is stored in a database residing on the server side. In the standard version of Focus the relational database has been implemented as a set of standard ASCII files. However the interface between the database and the Computation Layer is done through a dedicated API, in such a way that the database data can be easily ported to a commercial relational database system (RDBMS) such as ORACLE.

Both the client and the server part run under UNIX and Windows. Any combination of the two operating systems is possible (UNIX/UNIX, UNIX/Windows, Windows/Windows, Windows/UNIX). Virtually all flavors of UNIX are supported, including Linux. At the client side any of Windows 95/98/2000/NT/XP are also supported. This allows complete portability of the system.

4.0 FOCUSSUITE GUI

focusSuite GUI is largely based on a proprietary toolkit for rapid GUI development called tkforms that has been developed by GMV. The tkforms toolkit is a piece of middleware that allows GUI development based on configuration files rather than on code (more details are provided in the following sections).

The most outstanding features of the focusSuite GUI are:

- **Efficiency and ergonomics:** Current Flight Dynamics GUIs do not fully exploit capabilities for easing the access of the data and facilitating the use of the system. The figure below shows a screen shot of the focusSuite GUI and highlights some of the advantages that the GUI brings.
- **Additional functionality, reliability, efficiency:** The new GUI not only brings substantial improvements in terms of efficiency and ergonomics but also provides additional functionality, including:
 - Detailed Events Logging mechanism including capabilities to visualise key results characterising the execution of the programs and therefore allowing for very efficient monitoring of station keeping planning procedure behaviour both in manual and automatic mode.
 - Capability to perform unlimited Undo and Redo operations which represents a dramatic improvement of the system in terms of reliability. Every data modification and program execution operation can be undone and redone.

- Advanced data management capabilities including the possibility to manage data sets (duplication, modification, deletion). The GUI includes the concept of private and public data sets thus reinforcing the reliability of the operations performed with the system and enabling far more efficient concurrent use of the system. Also capability for the user to perform on the fly duplication of operational data for performing trial executions before bringing data operational.
- Improved mechanisms for work groups (concurrent system access), dramatically improved locking mechanisms.
- Capability of integrating new pieces of software without the need of performing software rebuild, making maintenance a lot easier and dramatically less costly.
- **Ease of use and learning curve:** from the screen shot shown below it can be observed that the focusSuite GUI represents a dramatic improvement in terms of ease of use and learning curve of the system. The system offers two levels of grouping of tasks that can be customised for each customer, therefore being capable of adapting to different operational approaches. Moreover, the system can be customized such that at any time the user is confronted with the normal sequence of operations making the system extremely easy to use.
- Additional **graphic capabilities** to the system will dramatically improve the productivity of the operations staff and provide a user-friendlier environment. A better output would also provide better view and better understanding of the results. In summary productivity and reliability will both be considerably improved. There are three types of graphical information to be presented to the user, each of them visualized by a dedicated tkforms widget:
 - X-Y plots (for example orbital elements versus time or orbit determination residuals) provide by focusGrafos component
 - Events (for example Orbital Events or a Timeline) managed by the
 - 2D/3D orbit visualization using the VisualFocus component

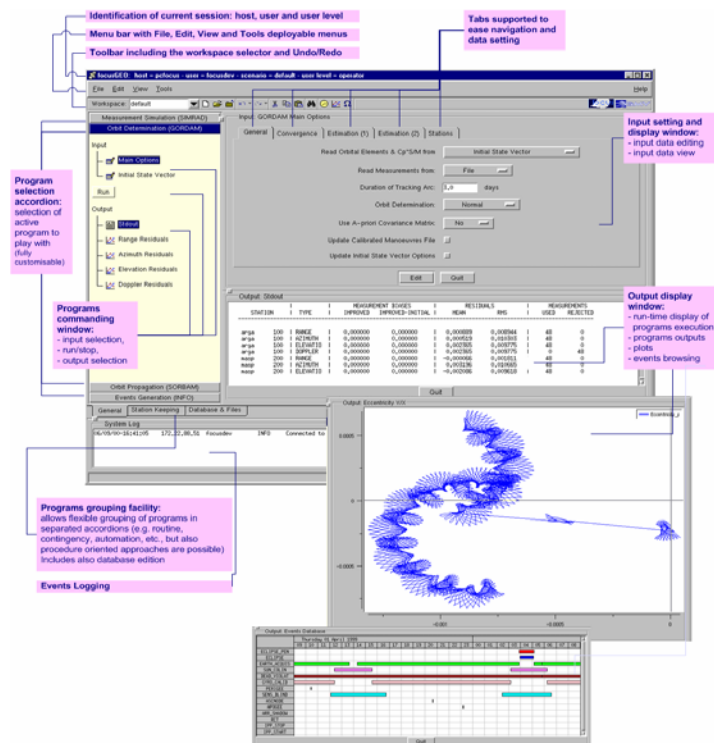


Figure 2 System GUI.

Framework Concept for Satellite Operations

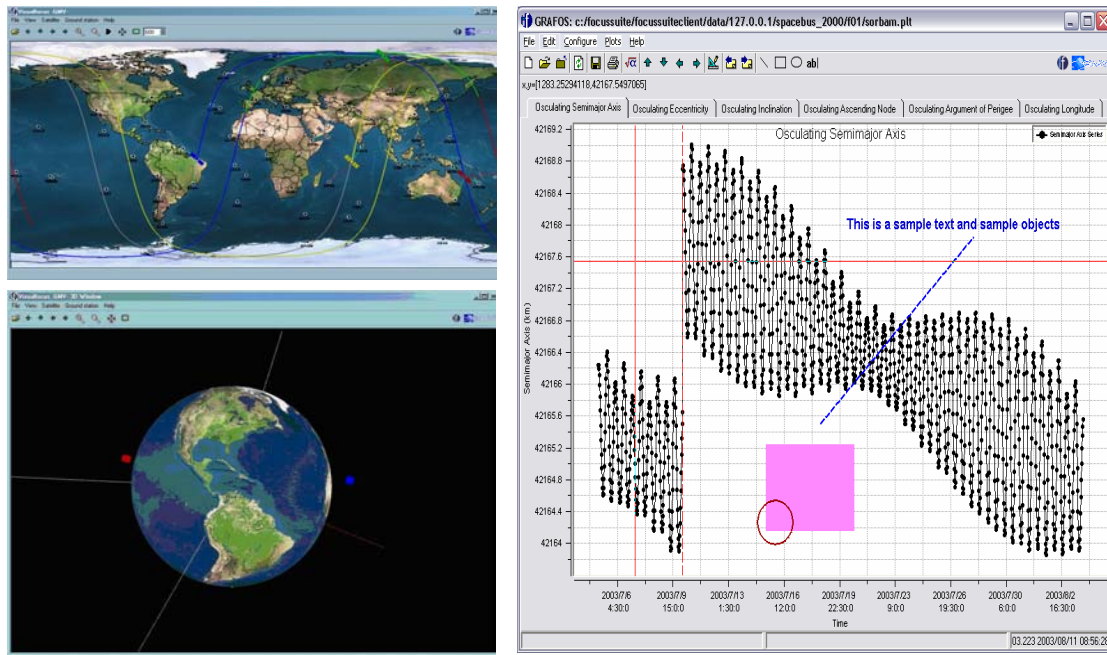


Figure 3 2D/3D Visualization capabilities (VisualFocus/ focusGrafos).

5.0 HOW INTEGRATE APPLICATIONS

On the following we are listing the requirements on any given application (program) to be integrated into the focusSuite framework:

- focusSuite data is organised in data structure composed of three levels (system, scenario and workspace). The data of the external application shall be adapted to this structure.
- The developer shall create the configuration file of the program (COF file), which defines the environment of the program, containing the definition of datasets (inputs and outputs) required to run the associated program by the process manager.
- The program shall have at least one main input dataset and one Autofocus specific dataset, the latter one being required only if we want to invoke the corresponding program from Autofocus. There is also a specific dataset naming convention to be applied.
- Both the main input dataset and the Autofocus specific dataset shall be compatible with the Tkforms component, which provides the data access services used by the data manager component. This is a crucial requirement if we want to get access to the inputs and output of a program from Autofocus.
- The developer shall create the Client GUI configuration files. These files also shall be compatible with the Tkforms components. The client GUI allows the user to get data access, to command program execution and to browser program results. Access to these functions is enabled through configuration files as described later.

Tkforms toolkit provides all data access services including GUI panel edition and data access libraries to be used from computation programs. Notice however that the computational programs do not necessarily have to use the Tkforms library to access the data, though this is highly recommended. A common data file format (TKF) and the use of this toolkit improve commonality throughout the system and allows faster

development of new components and easier integration of new components (such as new computation programs). In particular, the GUI, the DataManager and [AutofOCUS](#) use this toolkit.

The idea behind [Tkforms](#) is to split data content and data visualisation in two (or three) different files:

- Configuration file: written in very simple language and containing the details on how the data will be accessed and visualised. These details consist of the type, the layout, format and description of the parameters, etc. A typical definition of a piece is

```
integer
<
name `ITEM1'
label `An Integer:'
format `i7'
units `deg'
iulim 1000
illim -1000
help `This is an integer number'
>
```

- Data file: contains the actual data either as a sequence of pairs identifier/value or as list of values. When a program or application requires a data file with more complex structure than the standard, it is necessary to combine this data file with the wildcard file.
- Wildcard file: this is used for non-standard [Tkforms](#) data files and works as a template of the data files. This file is a copy of the data file in which it has replaced the values by @.

The types currently supported by standard [Tkforms](#) are:

- **Separator**: This item does not correspond to any data element. Only it is used by graphical modules (i.e focusPanel which generate a horizontal line).
- **Tabs**: This item does not correspond to any data element. Only it is used by graphical modules (i.e focusPanel which generate a new tab page).
- **Integer**: This item corresponds to an integer datum. It is a elementary item.
- **Real**: This item corresponds to a real datum. It is a elementary item.
- **String**: This item correspond to a string datum. It is a elementary item.
- **Epoch**: This item corresponds to a date datum. It is a elementary item.
- **Array**: This item correspond to a vector of dimension 1xN. It is a elementary item.
- **Yesno**: This item correspond to a logical datum. It is a elementary item.
- **Menu**: This item correspond to a enumerate datum. It is a elementary item.
- **List**: This item correspond to a list of records. It is a composed item, where each record is a finite number of elementary items.
- **Matrix**: This item correspond to a matrix NxM of real, integer or string data. It is composed item.

The consistency and coherence between the above set of files is crucial for the GUI and the rest of the system to work properly. [Tkforms](#) is the main mechanism that guarantees this consistency. Then additional modules translate the information stored in the [Tkforms](#) files in new components, which are integrated easily in high-level applications or computation programs.

Framework Concept for Satellite Operations

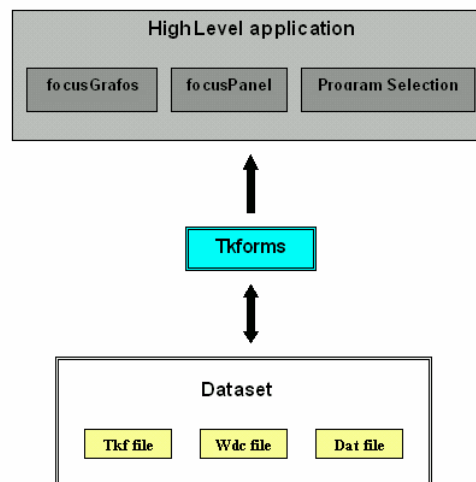


Figure 4 Tkforms concept.

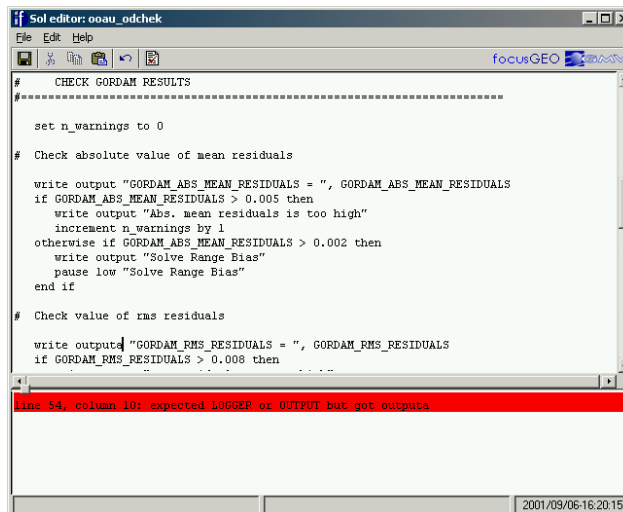
6.0 PROCEDURES AUTOMATION: AUTOFOCUS

Autofocus is an advanced component that delivers full automation support for hands-off operations to the entire **focusSuite**. The solution is based on an integrated set of tools for the definition, scheduling, execution, monitoring, and control of high-level user-defined operational procedures.

Autofocus is fully compatible with today's operations based on procedures, but assists the human operator by means of an agent that handles procedures written in SOL, the spacecraft operations language. **Autofocus** provides two user environments,

- one for procedure definition (the SOL factory),
- another for procedure execution (the procedure AGENDA).

SOL is a GMV automation language specifically designed to support spacecraft operations. Oriented towards spacecraft operators (not programmers), SOL is a very high-level language with natural language-like syntax in which the number of language elements has been minimised.



```

Sol editor: ooau_odcheck
File Edit Help
focusGEO
# CHECK GORDAM RESULTS
-----
set n_warnings to 0

# Check absolute value of mean residuals
write output "GORDAM_ABS_MEAN_RESIDUALS = ", GORDAM_ABS_MEAN_RESIDUALS
if GORDAM_ABS_MEAN_RESIDUALS > 0.005 then
  write output "Abs. mean residuals is too high"
  increment n_warnings by 1
otherwise if GORDAM_ABS_MEAN_RESIDUALS > 0.002 then
  write output "Solve Range Bias"
  pause low "Solve Range Bias"
end if

# Check value of rms residuals
write output "GORDAM_RMS_RESIDUALS = ", GORDAM_RMS_RESIDUALS
if GORDAM_RMS_RESIDUALS > 0.008 then
  ...

line 54, column 10: expected LOGGER or OUTPUT but got outputa
2001/03/06:16:20:15
  
```

Figure 5 Autofocus SOL editor.

SOL is a procedural language which features numeric, text, Boolean and date (relative and absolute) data as well as list handling.

A rich set of mathematical (trigonometric and hyperbolic functions, logarithms, power, etc.) and logical expressions (equal to, less than or equal to, logical **and**, **or** and **not**, etc.) is available in SOL. Date expressions and arithmetic operations are also supported, such as in:

```
set endEpoch to today + maneuverDuration
increment eclipseDuration by 0.5 hours
```

In the above example **today** gets substituted by today date.

SOL features the ability to call **procedures** from within other procedures. Procedure call, via the **execute** construct, allows to explicitly enumerate the inputs and outputs of a procedure for improved legibility:

```
execute orbitDetermination
  & inputs are
  &   set satellite to "H02"
  &   set epochStart to 22-jul-1999
  & outputs are
  &   set newStatus to status
  &   set newOrbit to orbit
```

SOL control structures include branching via **if/otherwise/end if** and flexible looping: repeat a block of instructions a fixed number of times (**repeat for/end repeat**), repeat while a condition is true (**repeat while/end repeat**) and iterate over the elements of a list (**repeat for each/end repeat**). For example:

```
repeat while residuals > 1.0e-3
  # Perform computation here
end repeat
```

SOL supports the whole focusSuite for full focusSuite framework automation. It is possible, for example, to activate external focusSuite components from a SOL procedure, collect its output and process it afterwards.

The Autofocus integrated procedure definition environment allows the user to write, validate and test procedures.

- Writing SOL procedures: The Autofocus SOL editor includes all features common in text editors (search, search and replace, copy, paste, ...) as well as providing SOL syntax coloring and contextual help and examples for all SOL syntax elements.
- Validating SOL procedures: SOL has been designed so as to allow extensive static procedure validation, both at the syntactic (keywords incorrectly spelled, incorrect expressions, a missing **end repeat** construct, ...) and semantic (executing a procedure with an incorrect set of inputs, trying to add two absolute dates, ...) levels. The validation feature ensures that procedures scheduled for execution are free of all but run-time execution errors (such as a division by zero).

Errors found when validating SOL procedures are displayed in a dedicated window: click on an error and the editor automatically jumps to the offending line. Contextual help for all errors is available.

- Testing SOL procedures: The Autofocus integrated procedure definition environment allows to test validated SOL procedures in a safe way so as not to modify operational data.

SOL procedures can be run in debug mode, providing controlled execution (line by line, jump to a given line or breakpoint, etc.) and introspection capabilities (showing the list of defined procedures with their inputs and outputs, the list of defined variables and their contents, etc.). A

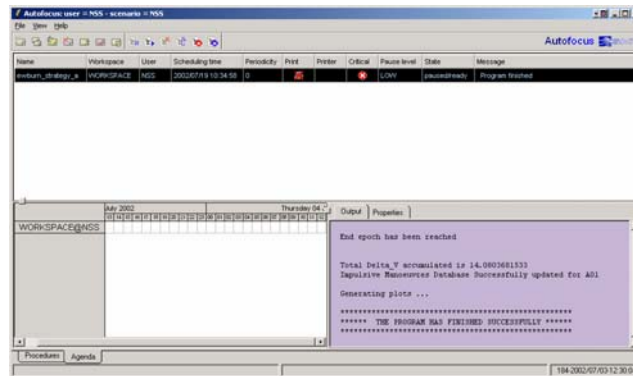


Figure 7 Autofocus procedures agenda.

7.0 OPERATIONAL EXPERIENCE: FOCUSGEO

focusSuite has been progressing in a phased approach and the several operational members of this family have been developed, in particular focusGEO product has been conceived in order to provide a new generation Flight Dynamics product for geostationary satellites.

This focusGEO version is now available and operational at HISPASAT and EUTELSAT. This tool is used as part of the end-to-end activities from Flight Dynamics point of view. In particular the following operations are executed using focusGEO:

- Routine and contingency operations over more than 20 satellites under control by EUTELSAT and over 4 satellites under control by HISPASAT. Routine operations include at least the following capabilities:
 - orbit determination and manoeuvres estimation,
 - orbit propagation,
 - manoeuvres computation,
 - manoeuvres calibration,
 - manoeuvres implementation and TC computation,
 - events computation,
 - reporting,
 - TM retrieval.
- Collocation routine operations, including combined ionic and chemical propulsion.
- Collocation cluster initialization.
- De-orbiting.
- Longitude relocation.
- Inclined orbit control (free inclination drift).
- Ionic propulsion management.
- Mass evolution and lifetime prediction.

focusGEO integrates the following elements as part the common focusSuite infrastructure:

- Mission independent SW inherited originally from PEPsoc, but highly modified by GMV internal developments and improvements of the original control algorithms, in particular

Framework Concept for Satellite Operations

optimization of the orbit control under critical constraints (e.g. reduced control window, high cross-coupling, etc.) Multi-satellite platform system: Astrium's Eurostar 2000/2000+/3000

- Alcatel's Spacebus 3000/3000B
- NPO/PM's SESAT (ionic propulsion)
- Alenia's SATELCOM
- HP376 Boeing (spinning satellite)
- FS1300 SS/Loral
- Collocation Station Keeping and Inclined orbit (in collocation also) Multiple reference frames
- Ion thrusting
- Reporting capabilities
- Contingencies and AOCS support
- LEOP support (launch window, transfer optimization)

From computational point of view we can highlight the following strategies:

- Orbit determination is based on a weighted least squares method able to estimate orbit, station biases, CpSM, delays, maneuvers.....using ranging, angular, doppler, turn-around, interferometry data.
- Numerical orbit propagator is based on a Runge Kutta, taking into account impulsive and continuous maneuvers.
- Maneuver computation is based on minimum fuel (several options depending on the cycle length,...) inclination control.
- Maneuver computation is based on sun pointing perigee strategy for eccentricity and longitude control. Additional eccentricity/longitude control strategies implemented for severe satellite constraints (reduce window, high cross-coupling).

REFERENCES

- [1] GMV S.A: "Introduction to focusSuite" v2.5. May 13th 2004.
- [2] GMV S.A.: "focusGEO User's Manual".
- [3] EUTELSAT FD maintenance handbook and operational procedures.
- [4] HISPASAT FD maintenance handbook and operational procedures.

BIOGRAPHY

Miguel Angel Molina is a Senior Aeronautical Engineer currently responsible of the Flight Engineering Business Unit at GMV S.A. This Business Unit is mostly dedicated to Flight Dynamics and Mission Analysis activities.



Framework concept for satellite operations

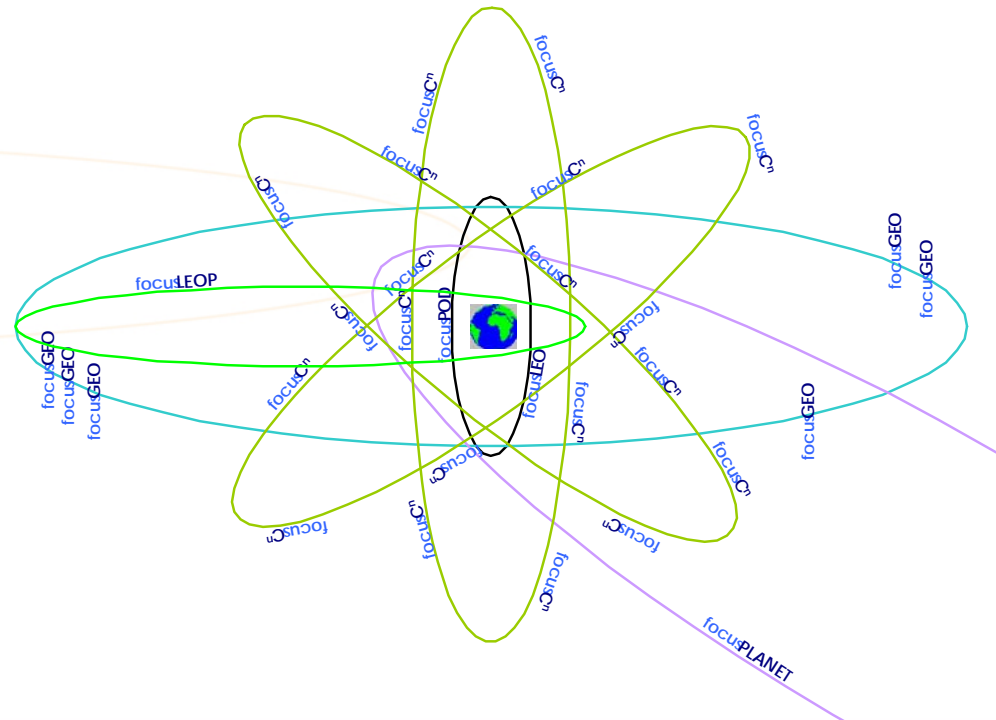
M. A. Molina, J. Prieto (GMV S.A.)
G. Garcia, T. Beech (GMV Space Systems)

www.focusSuite.com

www.gmv.com

Agenda

- 📍 GMV presentation
- 📍 Motivation and Profile
- 📍 Architecture
- 📍 Components
- 📍 focusSuite Family and Operational Experience

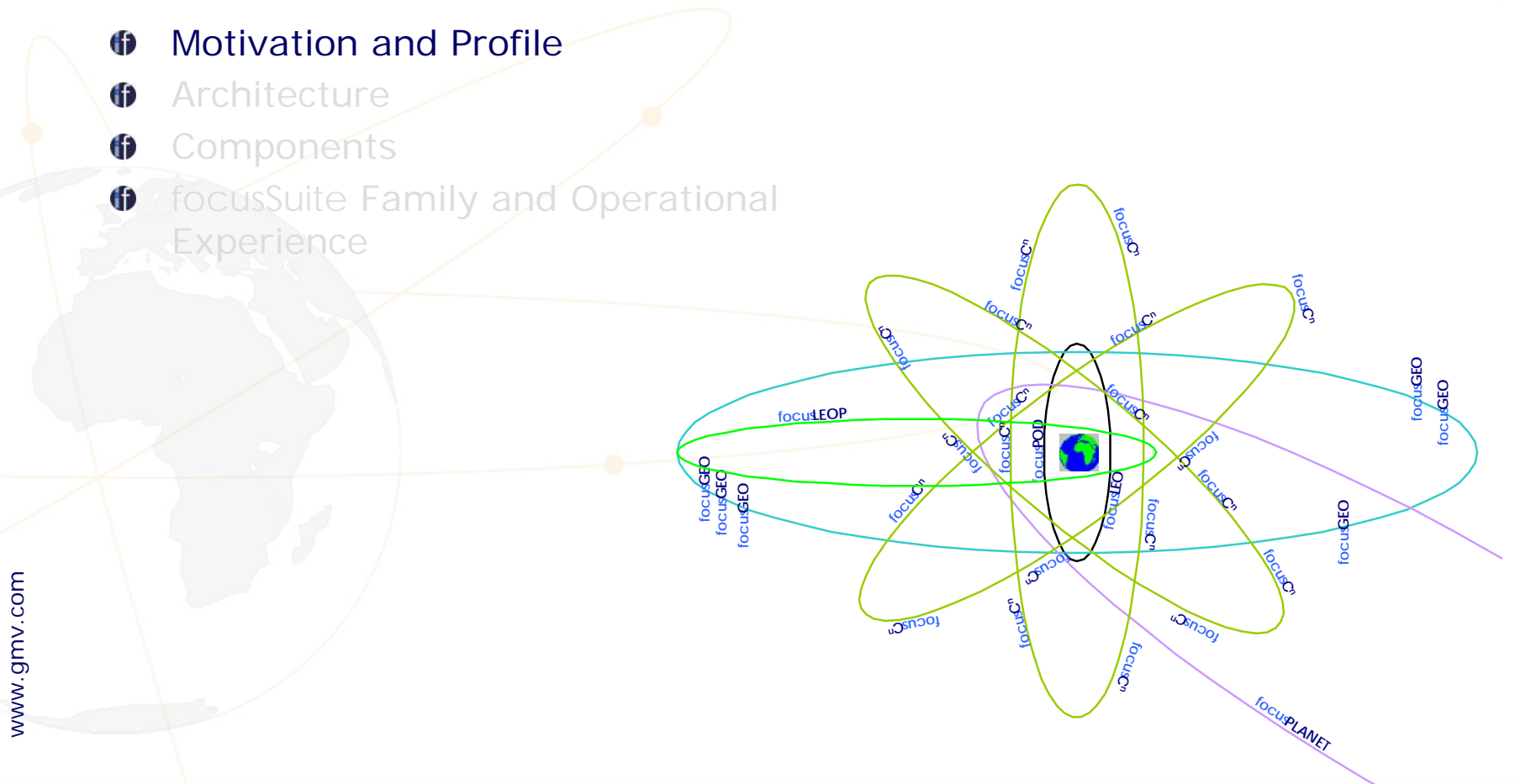




GMV Group



- Motivation and Profile
- Architecture
- Components
- focusSuite Family and Operational Experience



www.gmv.com

▣ Motivation

- ❏ background experience on satellite control systems
- ❏ design of new control systems is driven by
 - reuse of legacy software, exhaustively exploited during years: “flight proven”, versus new developments and
 - the use modern software technologies boosting system usability, accessibility and stability.
- ❏ “framework” concept appears as the required support for future control systems development.
- ❏ framework shall provides a number of ready to use components for data manipulation and visualization as well as event logging, communications, process management, automation and reporting

☒ Motivation

- ❏ framework initial objectives are:
 - to minimize programme development schedule, costs and risks, and
 - at the same time to improve the efficiency of operations (minimising operations workload) and reducing the risk of human errors
- ❏ the real power behind the framework lies in **its ability to integrate external components**
- ❏ GMV has developed an internal project, aimed at producing a new generation of control systems: **focusSuite**



▣ Requirements

📌 focusSuite framework :

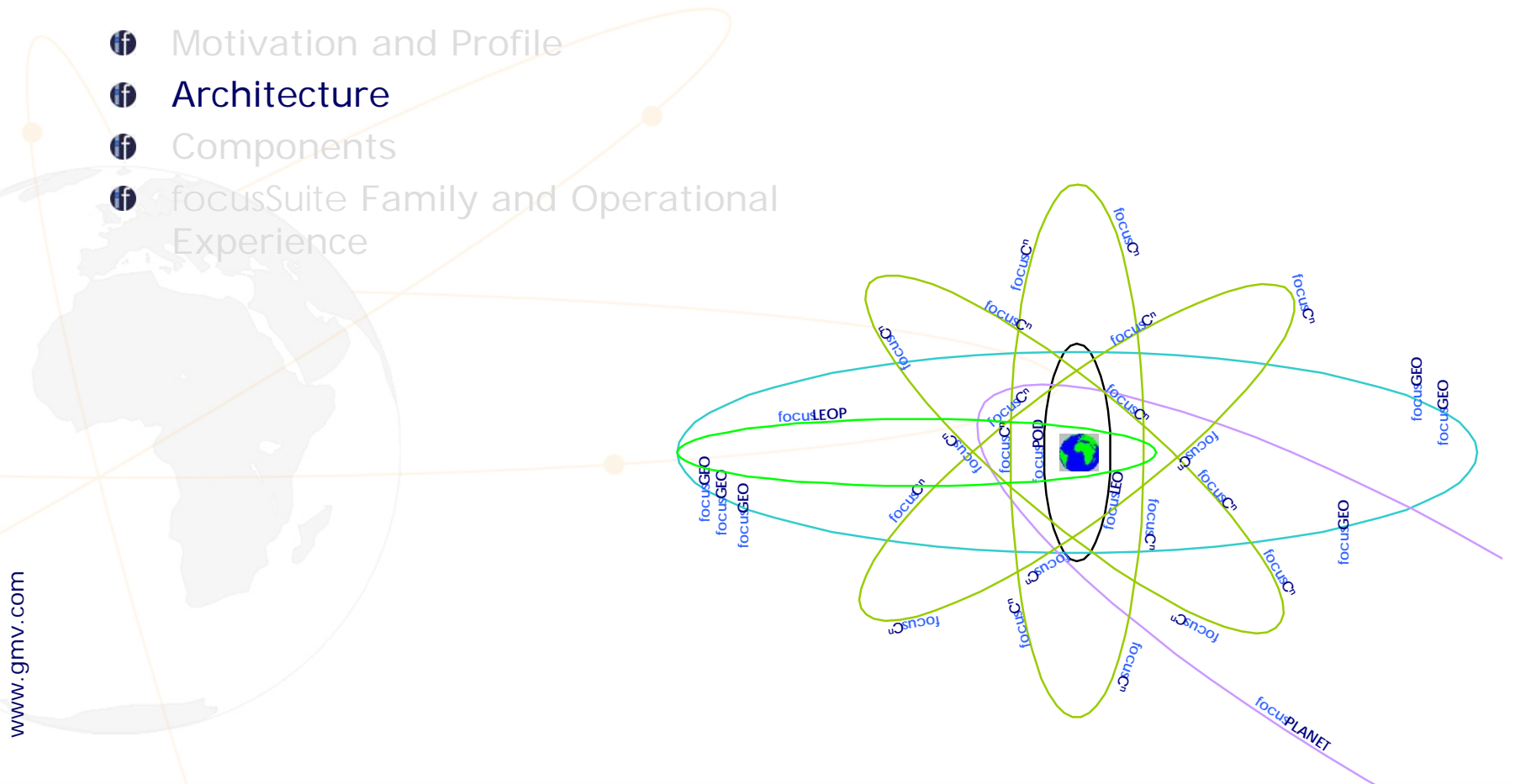
- is **mission independent**: generic infrastructure
- is ready for Real time and off-line capabilities
- is **portable** to any standard hardware (Unix,Windows,Linux)
- is **multi-satellite, multi-user**
- implement privileged data access mechanisms
- allows **concurrent access** and data access locking
- allows simultaneous operational scenarios
- has an advance/easy Man-Machine Interface
- performs **Undo/Redo** of all operations
- adds new programs to the infrastructure easily
- is able to operate any **third-party** software
- accepts **automation** of operations
- is free of third-party licenses, based on free software packages

Components

	Mission Analysis, Preparation & Support	Launch & Early Operations	Routine Operations
Generic Services (interfaces, database, comms, users management, internal API)	focusSuite	focusSuite	focusSuite
Advance MMI	focusGui		
Graphics	focusGrafos	focusGrafos	focusGrafos
Events	focusEbro	focusEbro	focusEbro
Real-time TM		focusTelma	focusTelma
Events Logging		focusEvelog	focusEvelog
Automation			Autofocus
2D/3D Visualisation	Visualfocus	Visualfocus	Visualfocus
Remote Operations			focusRemote
Data Export	OrbitML	OrbitML, focusNotes	OrbitML, focusNotes
Software Maintenance	focusArt	focusArt	focusArt

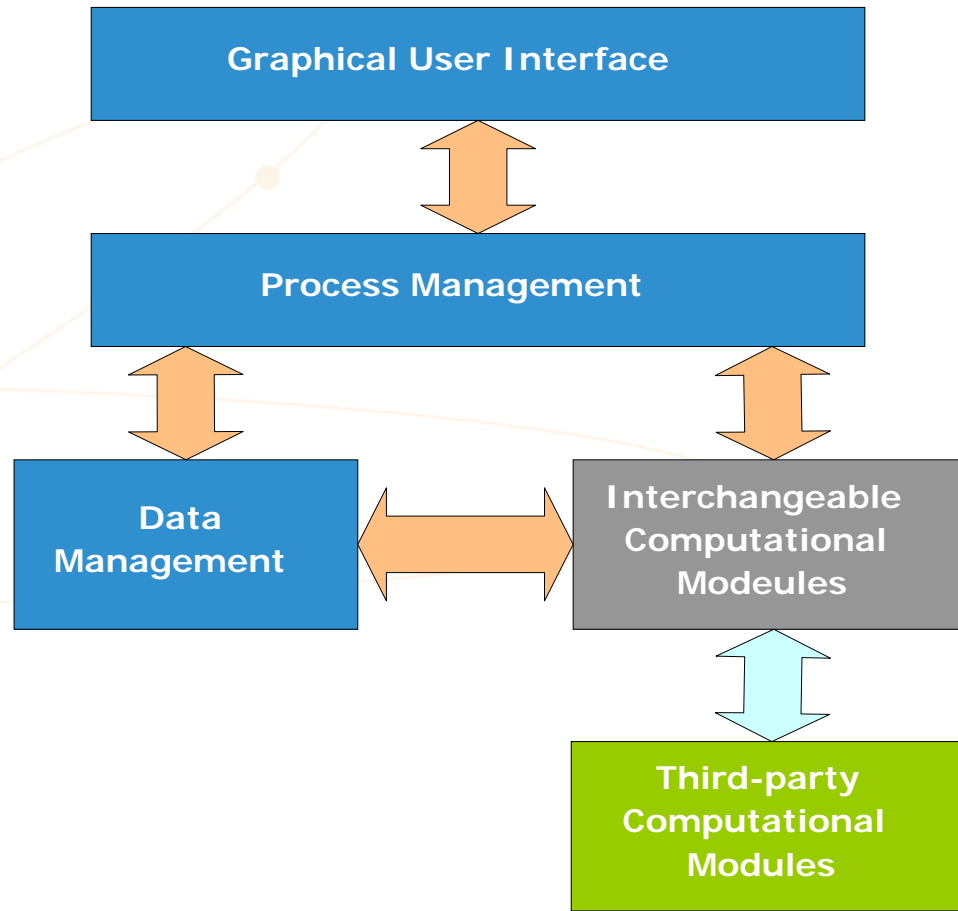
www.gmv.com

- Motivation and Profile
- Architecture
- Components
- focusSuite Family and Operational Experience

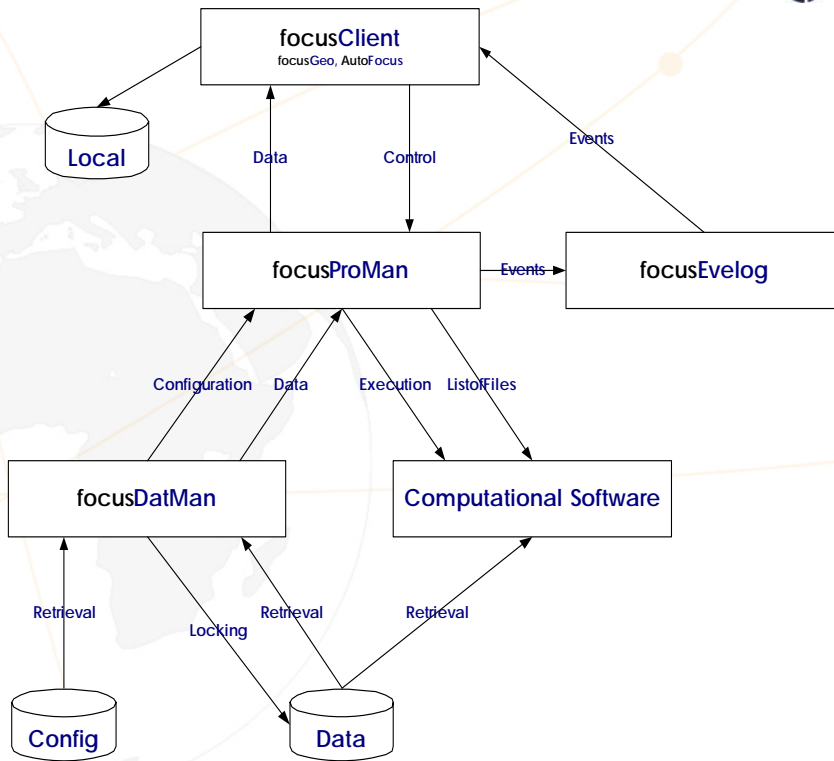


www.gmv.com

High-level Architecture





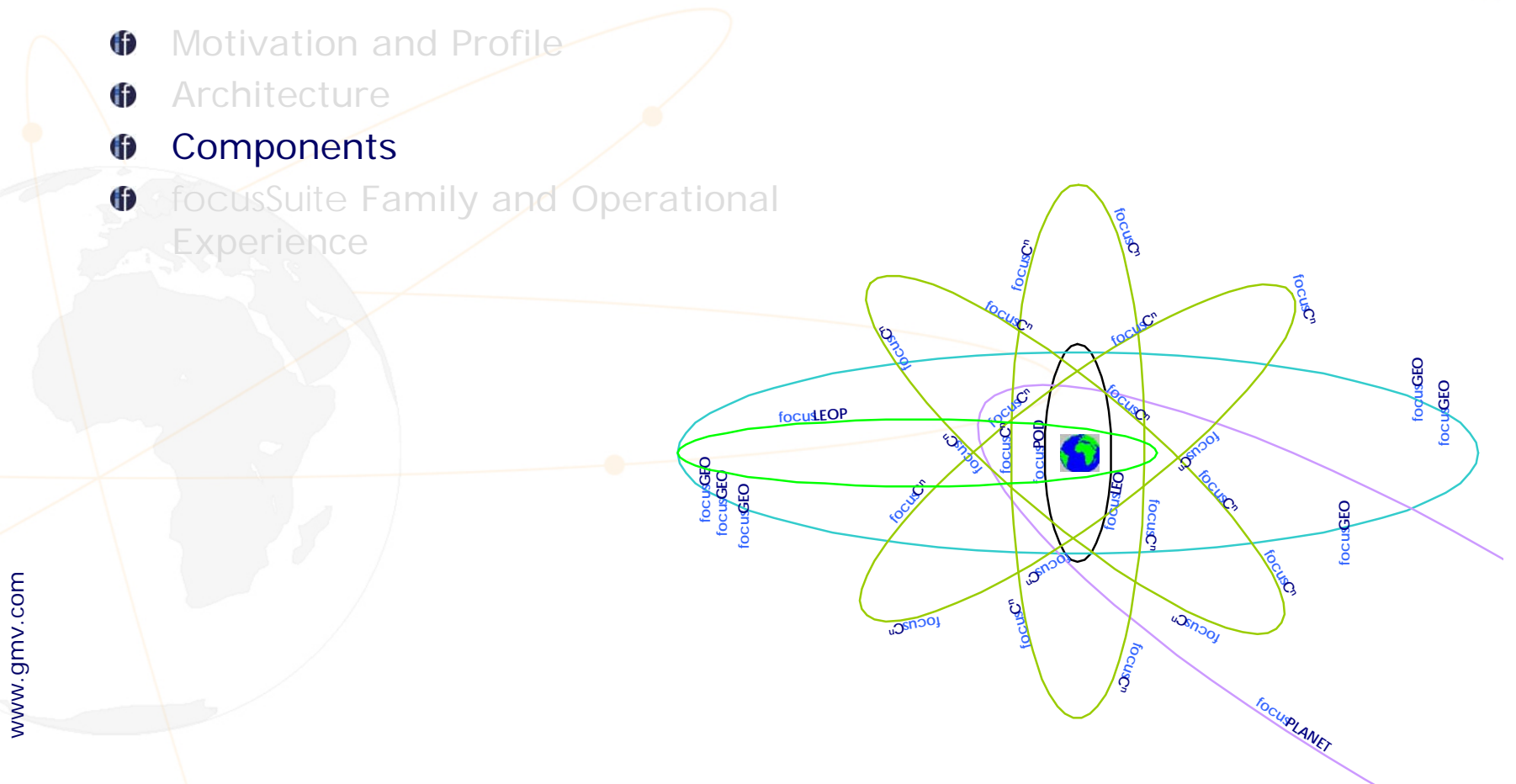
Client/Server Architecture



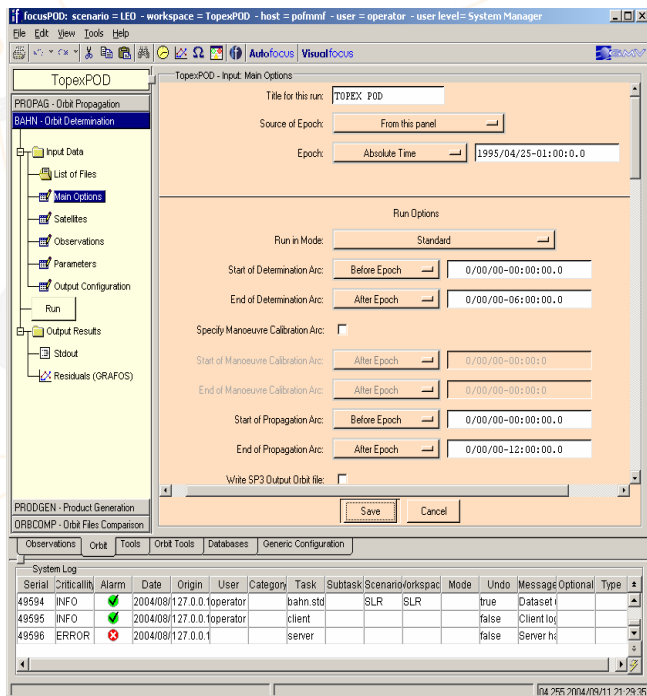
f A client/server architecture:

- All data and functionalities reside in the server
- Data and functionality requested by the clients to the server
- TCP/IP based communications
- Possibility to work over the Internet (security issue)

-  Motivation and Profile
-  Architecture
-  **Components**
-  focusSuite Family and Operational Experience



Man-Machine Interface



f An advanced MMI

- Integrates advanced widgets
- Design philosophy based on commercial desktop applications
- “everything-in-one-working-area”
- “all-one-click-away” (tabs)
- Based on Tcl/Tk
- 100% portable

f The proprietary toolkit TkForms

- Homogeneous data access
- Development through configuration
- Synchronisation of data access layer and computational layer

Man-Machine Interface

Identification of current session: host, user and user level

Menu bar with File, Edit, View and Tools deployable menus

Tools bar including the workspace selector and Undo/Redo

Tags supported to ease navigation and data setting

Input setting and display window:
- input data editing
- input data view

Program selection accordion: selection of active program to play with (fully customisable)

Programs commanding window:
- input selection,
- run/stop,
- output selection

Output display window:
- run-time display of programs execution
- programs outputs
- plots
- events browsing

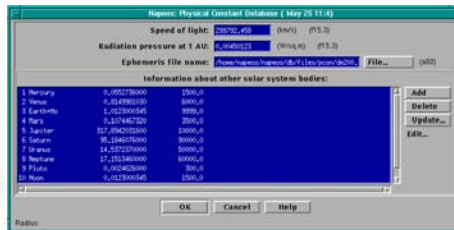
Programs grouping facility:
allows flexible grouping of programs in separated accordions (e.g. routine, contingency, automation, etc., but also procedure oriented approaches are possible)
Includes also database edition

Events Logging

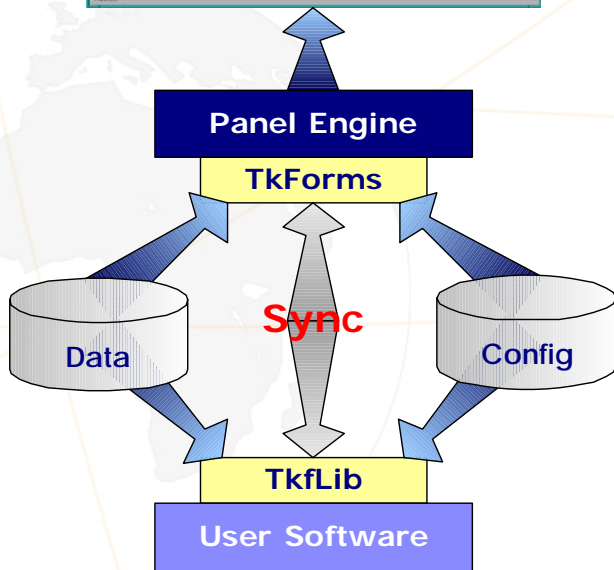
System Log

Date	Time	IP	User	Level	Message
05/25/00-07:34:52	172.22.88.51	focusdev	INFO	Connected to server	
05/25/00-07:35:37	172.22.88.51	focusdev	INFO	Request run sorbam	
05/25/00-07:36:55	172.22.88.51	focusdev	INFO	sorbam run successfully	
05/25/00-07:46:19	172.22.88.51	focusdev	INFO	Connected to server	
05/25/00-07:47:11	172.22.88.51	focusdev	INFO	Client logout	

Libraries: TkForms / TkLib

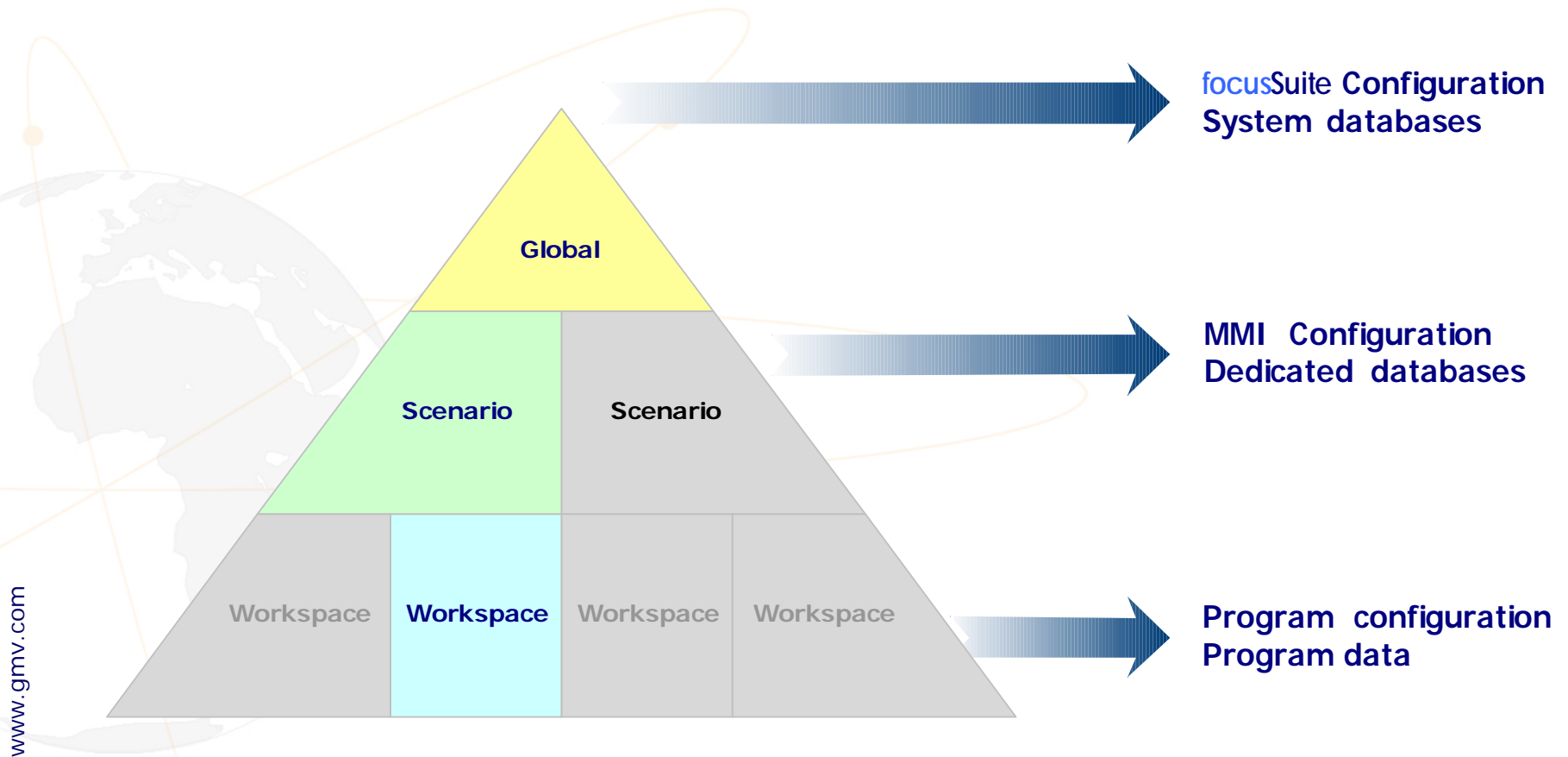


- f Key point in the success of focusSuite
 1. TkForms: interface to MMI dynamic panel generation
 2. TkLib : interface to user software data access
- f Decoupling of
 - Configuration and data
 - Infrastructure and user software
- f TkForms & TkLib synchronisation



www.gmv.com

focusSuite data structure



Database

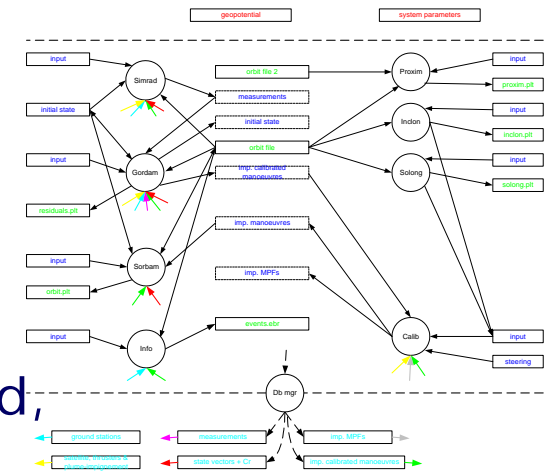
Database driven

- mission data stored in a database
- database in the server
- easy data import/export
- Application dependent

Database: Satellite, Station / Site, Payload, Tracking systems, Central body, Physical constant, Sensors

Interface between the database and the Computation Layer done through dedicated API.

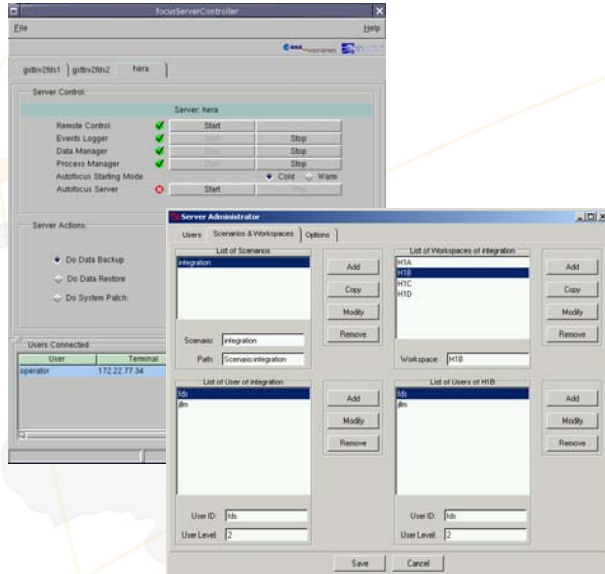
database data can be easily ported to a any commercial relational database system (RDBMS) such as ORACLE



Configuration

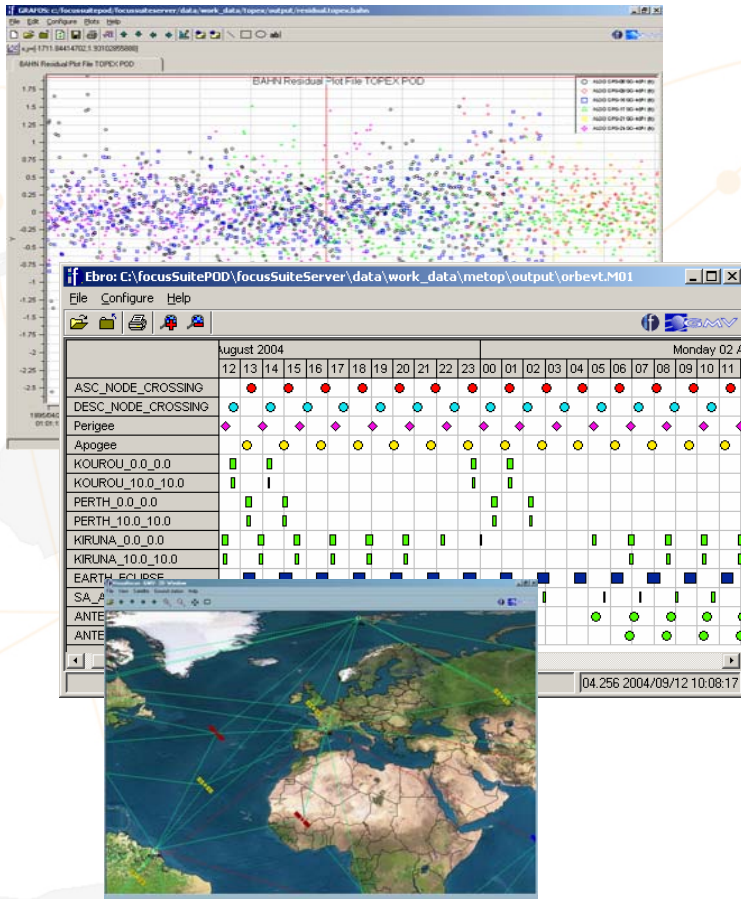
- Interface between the framework and the control algorithms is based on the implementation of an API in order to manage the processing and the data interfaces.
- Management of new entities to the system is performed by simply modifying editable configuration file
- Configuration files are interpreted by the framework system in order
 - to create the required database structure,
 - to construct the overall MMI and
 - to generate the flight dynamics functionality including generic functions like plotting or data acquisition and pre-processing





Server Administrator

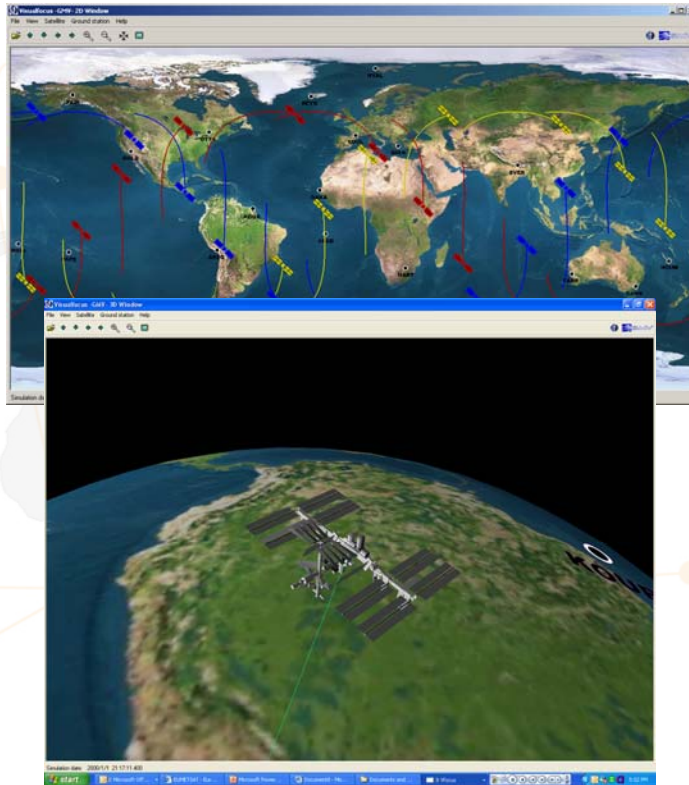


- f Configuration
 - User accounts
 - Scenarios / Workspaces
 - Privileges
- f Key aspect to
 - Concurrent access
 - Data locking
- f On-line tasks
 - Server status monitoring
 - Server start/stop
 - Server data synchronisation
 - Back-up/restore

Graphical tools

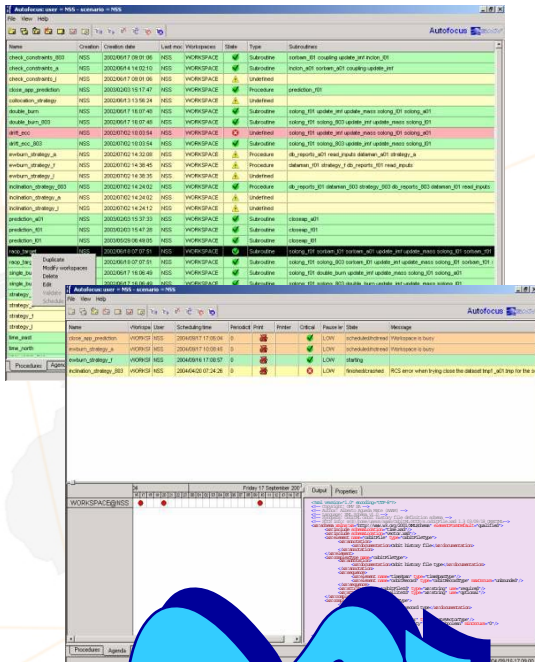


-  Widget oriented
-  Multi-format
 - by columns
 - Extensions: [OrbitML](#), [SP3](#)
-  Powerful configuration capabilities
 - Inspired in existing packages
 - Tuned to flight dynamics
-  Tools
 - [focusGrafos](#)
 - [focusEbro](#)
 - [Visualfocus](#)



- f 2D/3D visualisation tool
 - OpenGL technology (multi-platform)
 - Zooming and panning
 - Subjective view
 - Celestial bodies true ephemeris
 - Detailed maps and textures
 - Sensor view
- f Operation modes
 - Real-Time mode
 - Playback mode

Autofocus



- focusSuite automation component for hand-off operations.
- Fully compatible with today's operations based on procedures
- Components
 - Procedures definition tool
 - Agenda (Scheduler)
 - Procedures language (Sol)
- Sol (**S**pacecraft **O**perations **L**anguage)
 - Targeted to spacecraft operations
 - Very high-level

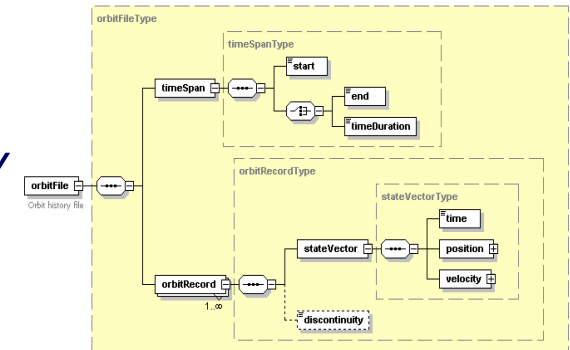


☑ Data Export: OrbitML

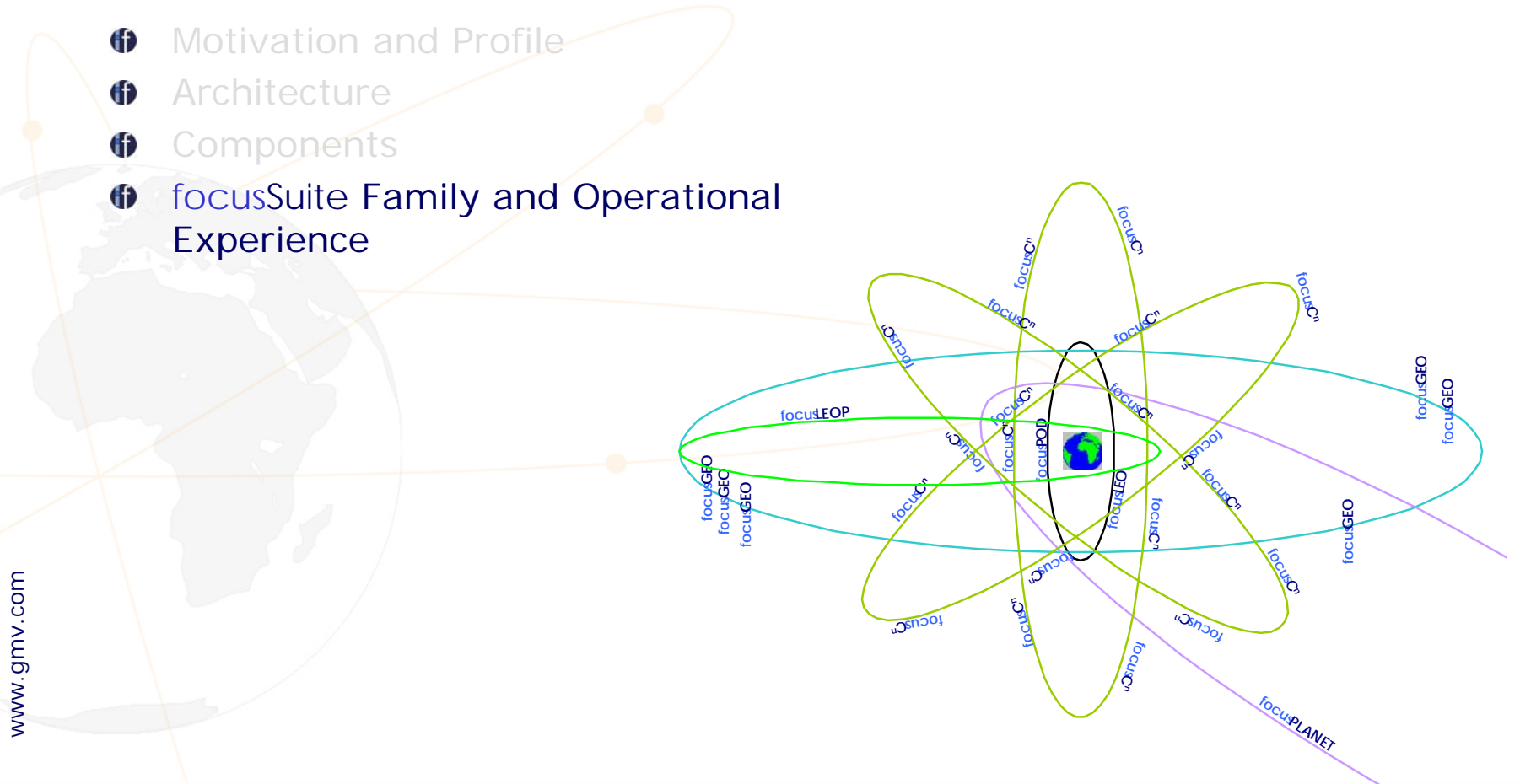
www.OrbitML.com



- ❏ data representation in XML and Defined with XML schema
- ❏ Design drivers
 - Heritage from *European packages* ...
 - Improved *consistency* and *portability*
 - *Readability*
 - Suitability for *automation*
 - Extensibility to other space applications
- ❏ CCSDS OPM/OEM XML representation supported by OrbitML



- Motivation and Profile
- Architecture
- Components
- focusSuite Family and Operational Experience

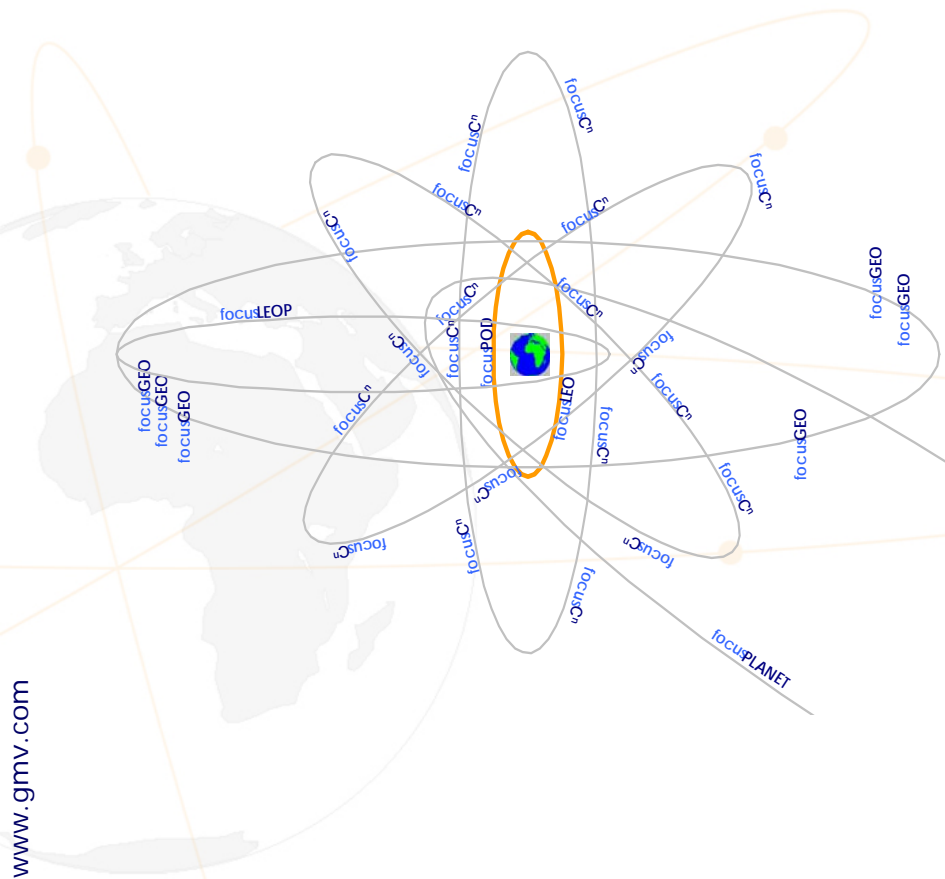


www.gmv.com

▣ Mission Profile Coverage

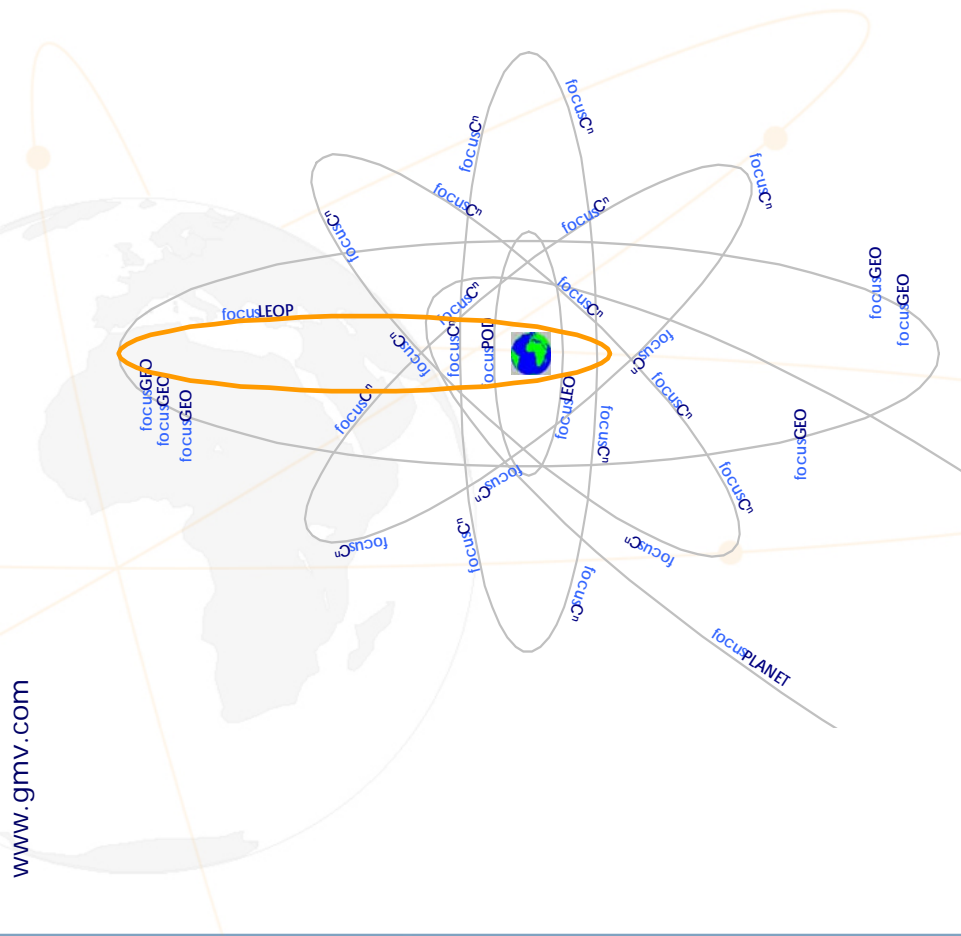
	Telecommunication	Earth Observation	Navigation	Scientific
LEO/MEO	focusCn	focusLEO	focusLEO focusCn	focusLEO
GEO	focusGEO	focusGEO	focusLEO	focusLEO
Interplanetary				focusPLANET
Re-entry				focusReentry
Launch/Ascent	focusAscent	focusAscent	focusAscent	focusAscent
FF and RdV	focusRdV	focusRdV	focusRdV	focusRdV
Multi-satellite	focusGEO	focusLEO	focusC ⁿ	
LEOP	focusLEOP	focusLEO	focusLEO focusC ⁿ	focusLEOP, focusLEO
POD		focusPOD	focusPOD	
Automation	focusGEO	focusLEO	focusC ⁿ	
Collision risk	focusCloseAp	focusCloseAp	focusCloseAp	focusCloseAp




focusLEO



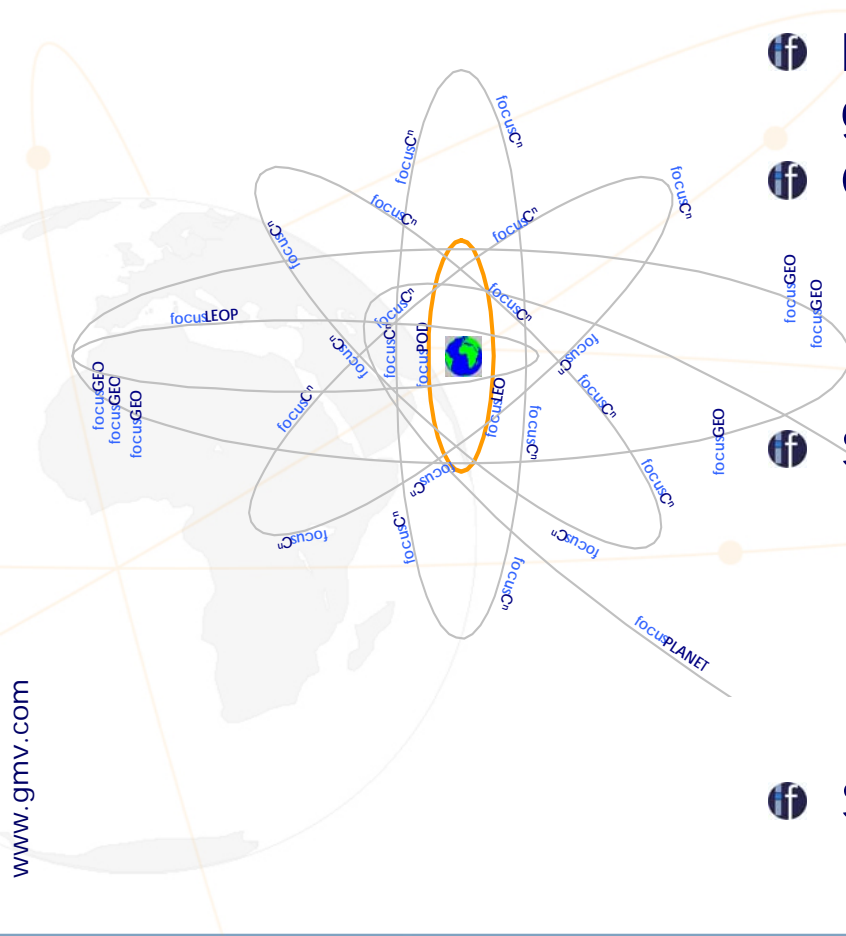
-  **LEO/MEO** missions
-  Computational layer
 - ESA NAPEOS
 - Enhancements from EPS Metop
-  GSTBV2 (first GALILEO satellite) implementation
-  Status: **Pre-Operational (Astrium Ltd)**

focusLEOP



-  **Launch and Early Orbit Phase**
-  **Computational layer**
 - focusLEO
 - Manoeuvre optimisation based on proprietary **AEFOS algorithm**
-  **Status: Operational (Parallel operations with HISPASAT)**

focusPOD



- ❶ Precise **O**rbit **D**etermination and geodesy

- ❷ Computational layer

- ❶ ESA NAPEOS version GPS

- ❷ Enhanced detailed models for POD

- ❸ Scenarios

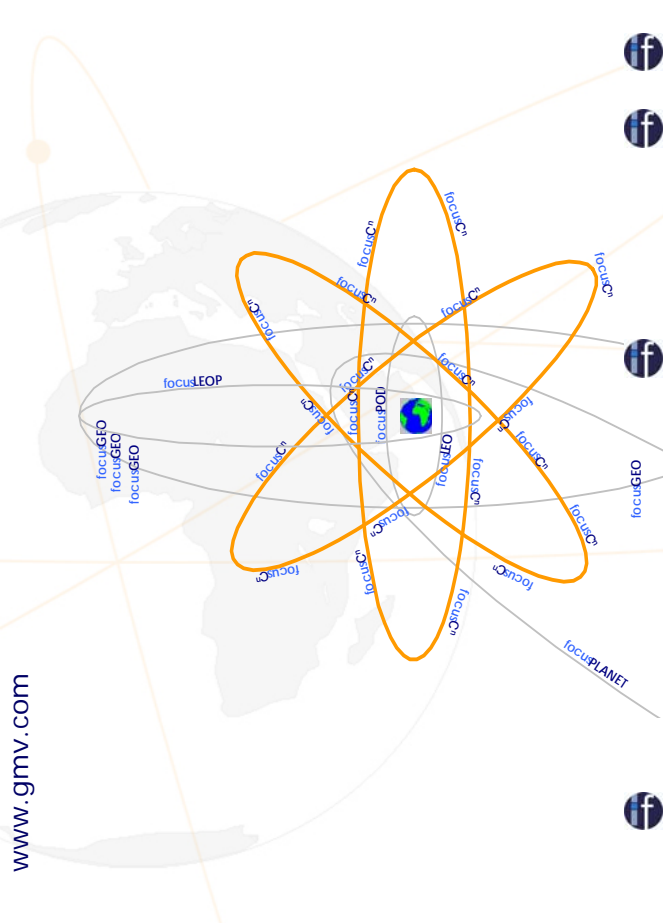
- ❶ GPS (IGS & LEO)








- ❷ SLR, DORIS & PRARE


- ❸ Altimetry

- ❹ Status: **Ready**

 focusCⁿ

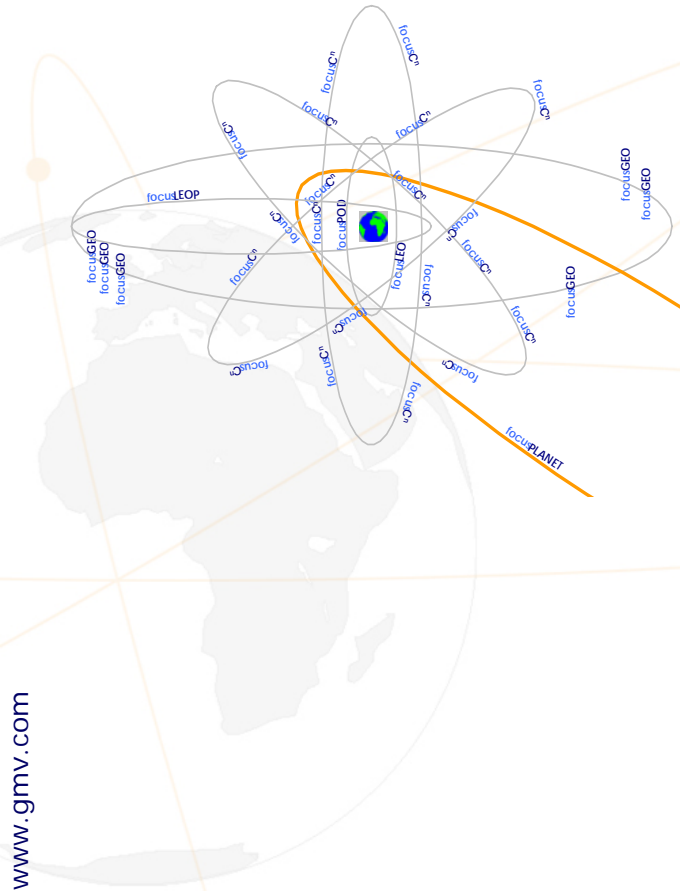






-  **Constellations** management
-  Computational layer
 - ESA NAPEOS version GPS
 - Components from focusLEO
-  Enhanced specific items
-  Specific widgets for constellations
-  Integrated constellation
 -  Management
 -  Performance monitoring

-  Status: **Under development for GALILEO**

www.gmv.com

focusPlanet/Reentry/Ascent/RdV

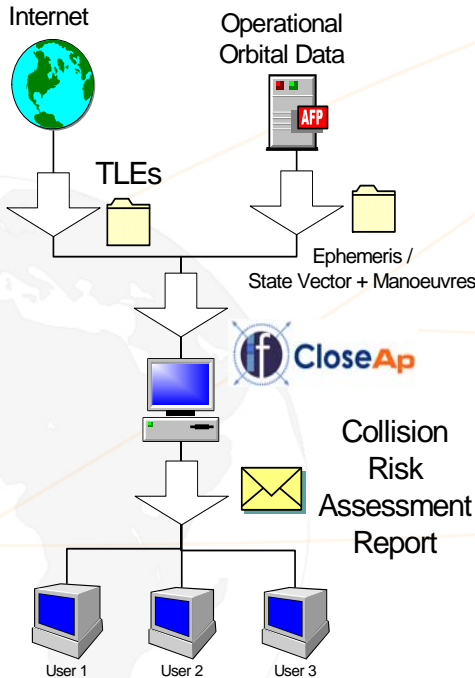





-  focusSuite for interplanetary and specific missions
-  Mission analysis
-  Internal R&D: Application of focusSuite in other areas of GMV expertise
-  Status: **Recent delivery to ESA (excepts for Ascent)**

focusCloseAp



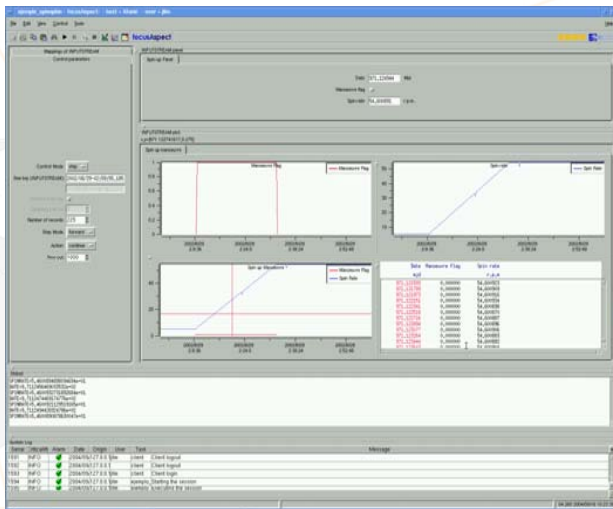
focusSuite



-  Generic collision risk assessment tool
-  Algorithms
 - Initial assessment through TLE
 - Combination with operational solutions
 - Improvement by GMV by proprietary adjustment
-  Status: **Operational GEO version (New Skies and HISPASAT)**

www.gmv.com

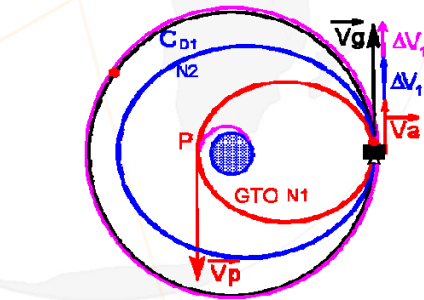
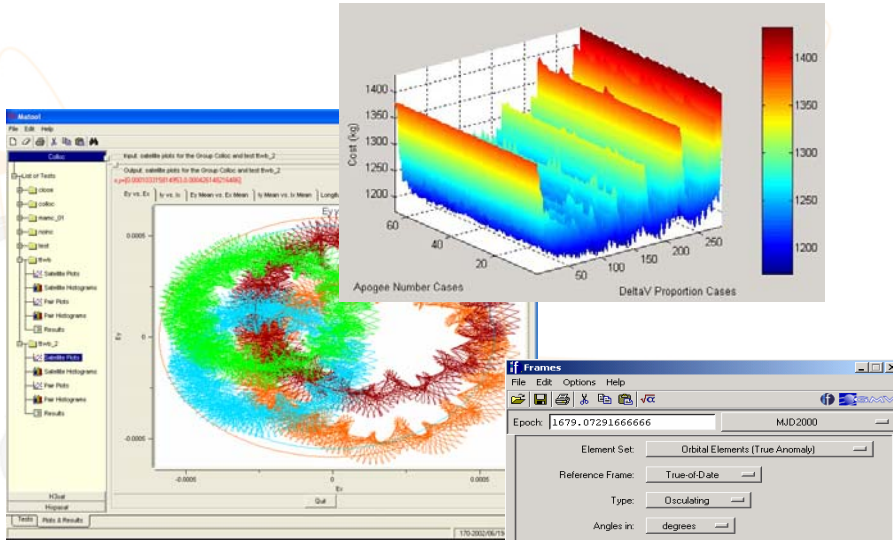
focusAspect



- AOCS Performance Evaluation and Calibration Tool**
- Generic real time telemetry monitoring system**
 - Dynamic interfaces loading
 - Dynamic users procedures loading
- Status: Under operational evaluation (ESA-ESOC)**

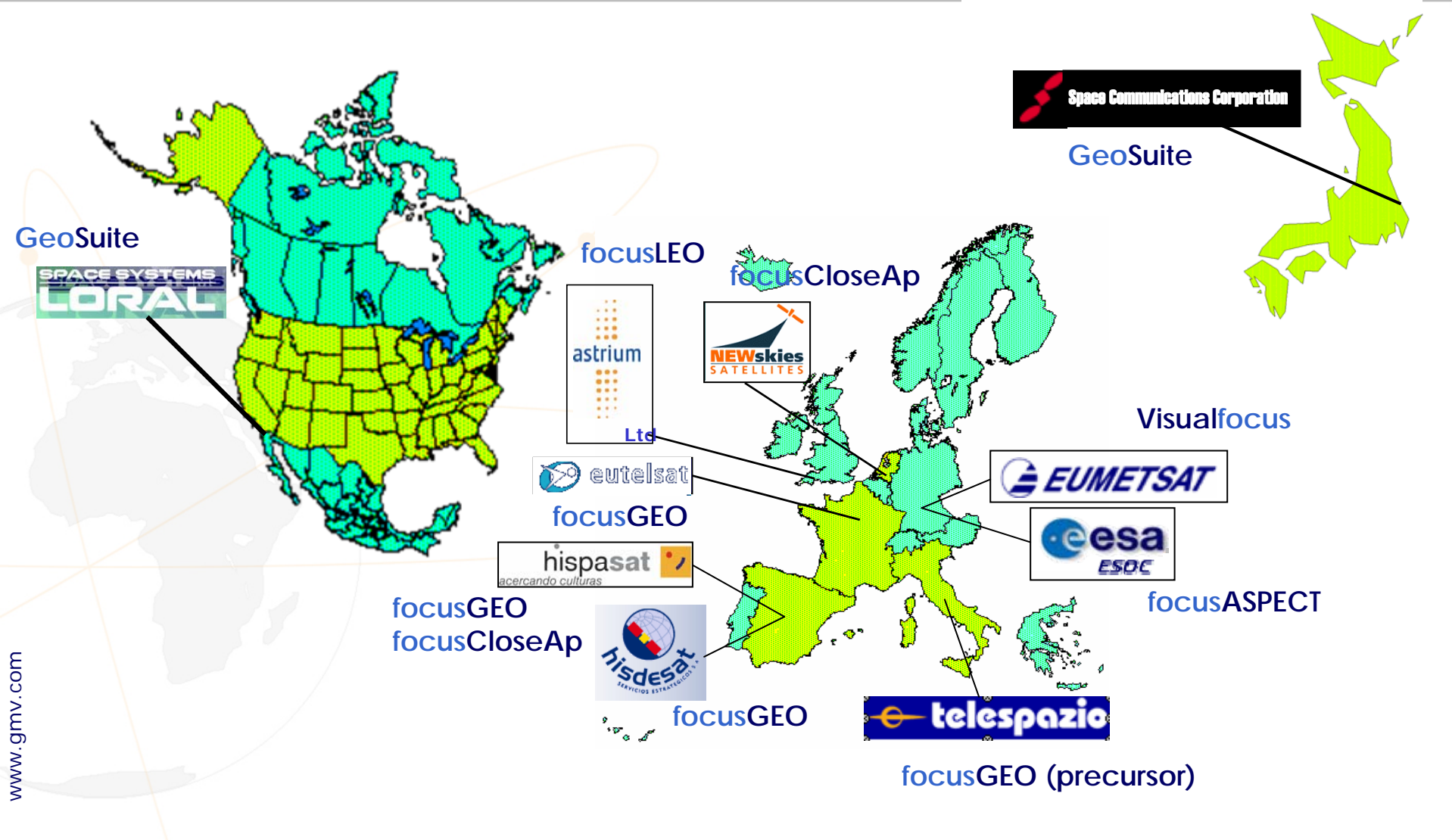


GeoSuite Mission analysis tools for GEO satellites



Element Set	Orbital Elements (True Anomaly)
Reference Frame	True-of-Date
Type	Osculating
Angles in	degrees
Orbital Elements	
Semimajor Axis:	25851.52001 Km
Eccentricity:	0.63227233
Inclination:	9.00533 deg
Ascending Node:	300.56133 deg
Argument of Perigee:	359.56518 deg
True Anomaly:	109.38827 deg
Element Set: Orbital Elements (True Longitude)	
Reference Frame	Mean-of-Date
Type	Osculating
Angles in	degrees
Orbital Elements	
Semimajor Axis:	25851.520010 Km
Eccentricity:	0.6322723300
Inclination:	9.0053316085 deg
Ascending Node:	300.54916284 deg
Argument of Perigee:	359.57977127 deg
True Longitude:	68.544809075 deg

- Station keeping and collocation control strategies design
- Transfer Strategy design
- Launch Window computation
- Tracking scenario analysis
- Time and reference frames conversion
- Status: **Operational (LORAL and SCC-Superbird)**



www.gmv.com

focusSuite



QUESTIONS ?