JSatOrb: ISAE-Supaero's Open-source Software Tool for Teaching Classical Orbital Calculations

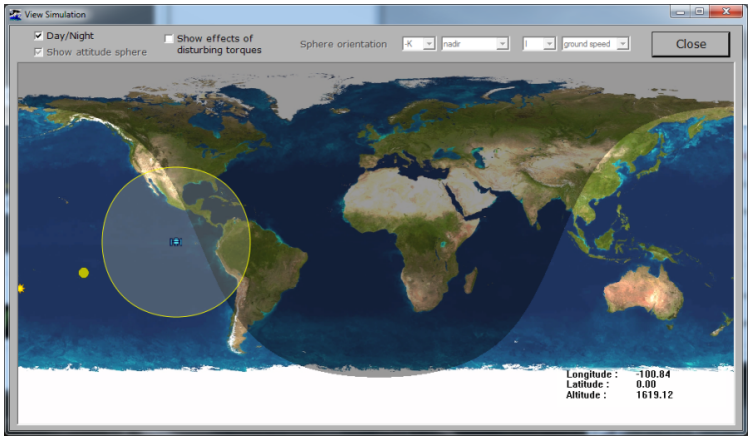
Thibault Gateau, Julio Hernanz-Gonzalez, Theo Koudlansky, Lucien Sénaneuch and Patrice Labedan

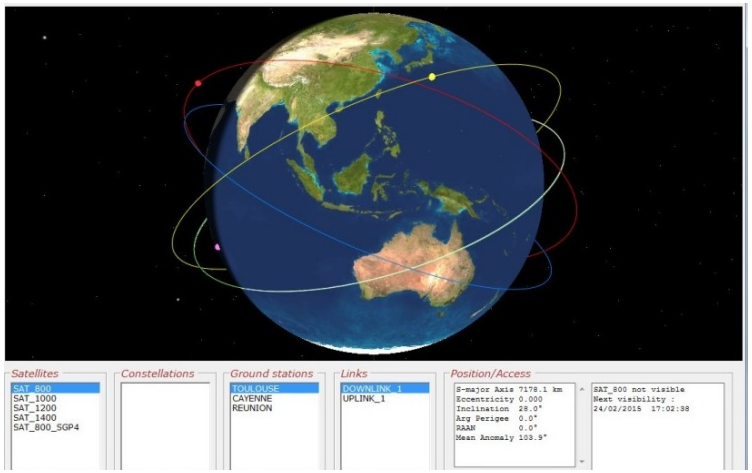
2018 November 7

ISAE-SUPAERO: Teaching Space Stuff

Teaching support

- Space Mechanics
- Mission Analysis
- Thermal Architecture
- Space Telecom
- Power system
- AOCS
- Launchers
- Project Management
- ...





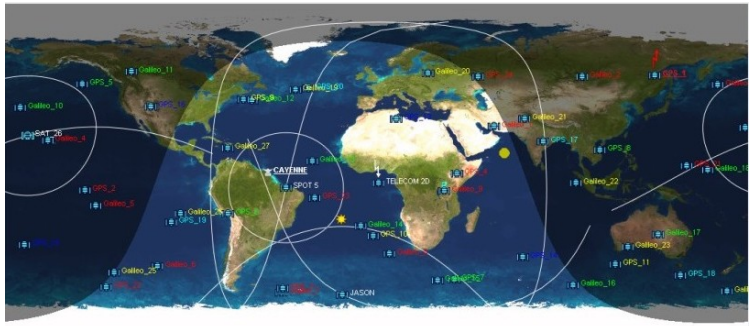
ISAE-SUPAERO: Doing Space Stuff

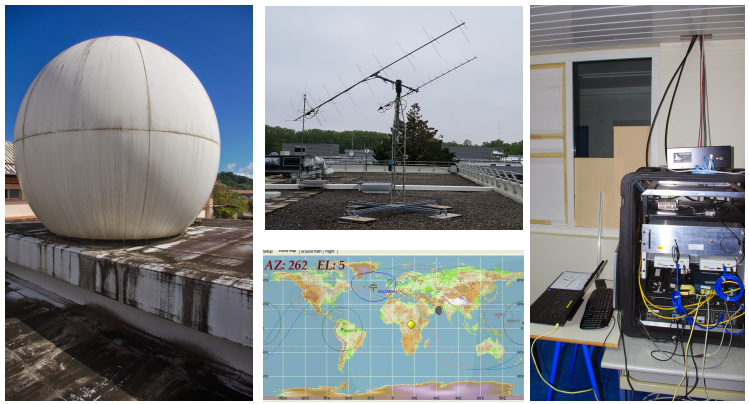
Research & Support

- Engineering Projects
- Research Projects

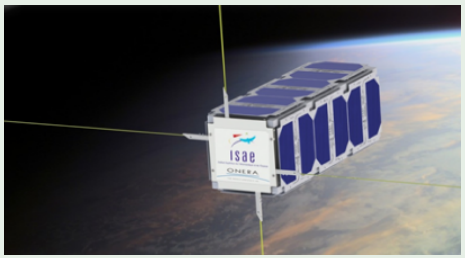
Facilities

- UHF/VHF antenna/station
- S-Band antenna/station
- Control Center
- Clean Rooms ...

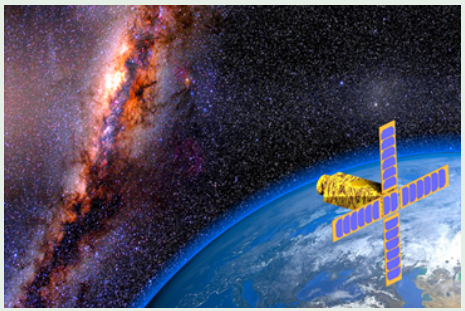




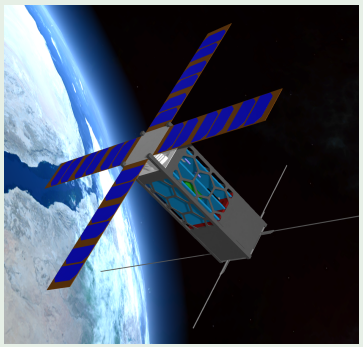
3U Nanosats projects on the way (more than these 3!)



- Entrysat
- Phase D



- Eyesat
- Phase D

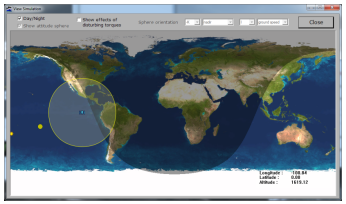


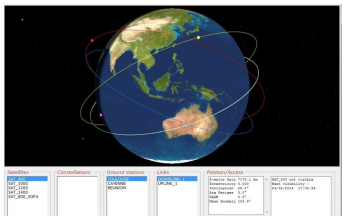
- Nimph
- Phase B1

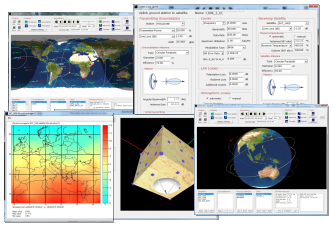
ISAE-SUPAERO Space Software Suite

People involved

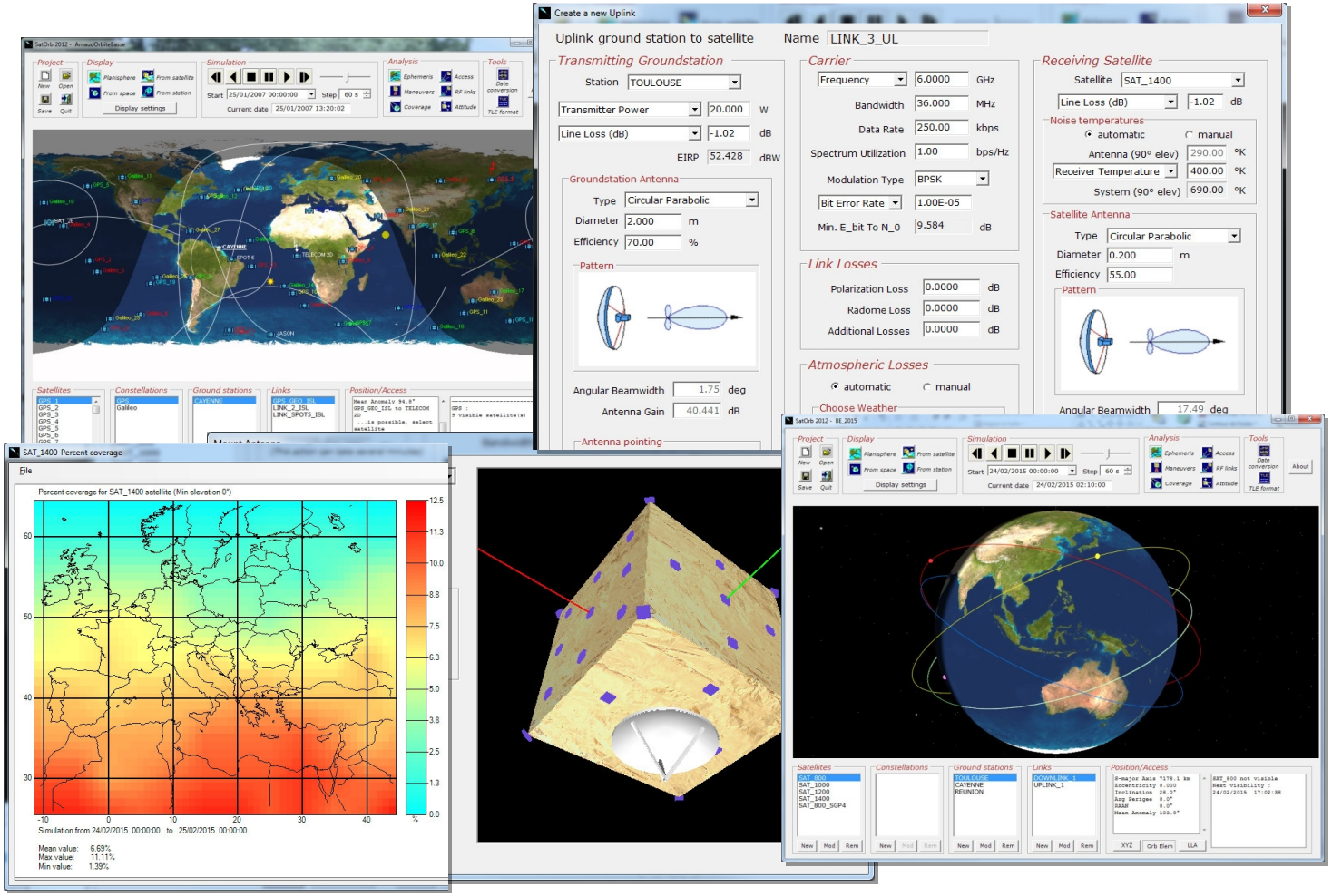
- Initiator (before 2001!):
  - Christian Colongo
- Current Dev Team:
  - Patrice Labedan
    - Guillaume Garrouste
    - Thibault Gateau
- Lot of support from:
  - Students Projects
  - Internships
  - PhD students
  - Collaborations (TUM)







Satorb


Create a new Uplink
Uplink ground station to satellite
Name LINK_3_UL
Transmitting Groundstation
Station TOULOUSE
Transmitter Power 20.000 W
Line Loss (dB) -1.02 dB
EIRP 52.428 dBW
Groundstation Antenna
Type Circular Parabolic
Diameter 2.000 m
Efficiency 70.00 %
Pattern
Angular Beamwidth 1.75 deg
Antenna Gain 40.441 dB
Antenna pointing
Carrier
Frequency 6.0000 GHz
Bandwidth 36.000 MHz
Data Rate 250.00 kbps
Spectrum Utilization 1.00 bps/Hz
Modulation Type BPSK
Bit Error Rate 1.00E-05
Min. E_bit To N_0 9.584 dB
Link Losses
Polarization Loss 0.0000 dB
Radome Loss 0.0000 dB
Additional Losses 0.0000 dB
Atmospheric Losses
automatic
manual
Choose Weather
Receiving Satellite
Satellite SAT_1400
Line Loss (dB) -1.02 dB
Noise temperatures
automatic
manual
Antenna (90° elev) 290.00 °K
Receiver Temperature 400.00 °K
System (90° elev) 690.00 °K
Satellite Antenna
Type Circular Parabolic
Diameter 0.200 m
Efficiency 55.00
Pattern
Angular Beamwidth 17.49 deg
SAT_1400-Percent coverage
File
Percent coverage for SAT_1400 satellite (Min elevation 0°)
Simulation from 24/02/2015 00:00:00 to 25/02/2015 00:00:00
Mean value: 6.69%
Max value: 11.11%
Min value: 1.39%

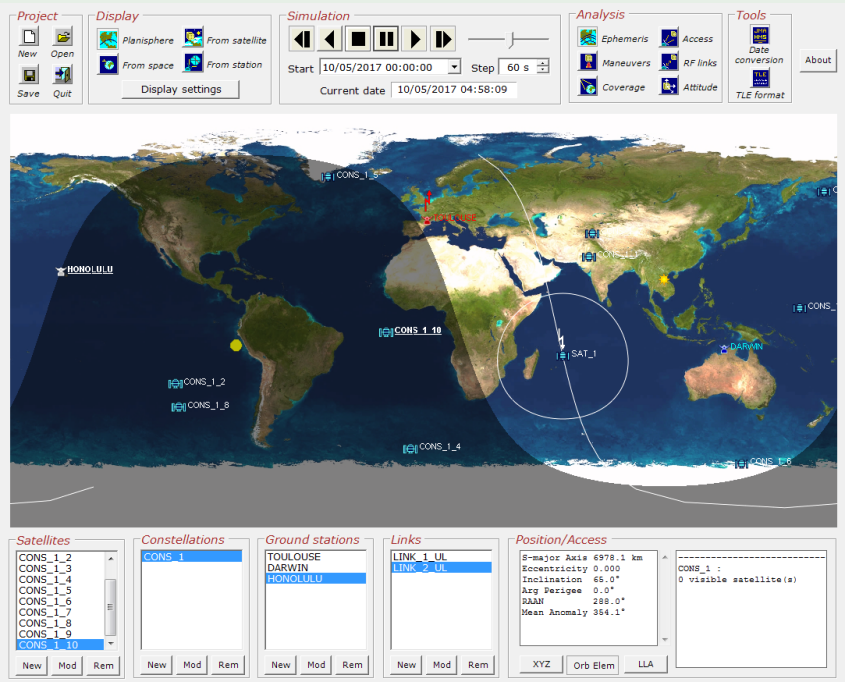
Functionnalities

[Hernanz-Gonzales 2017]

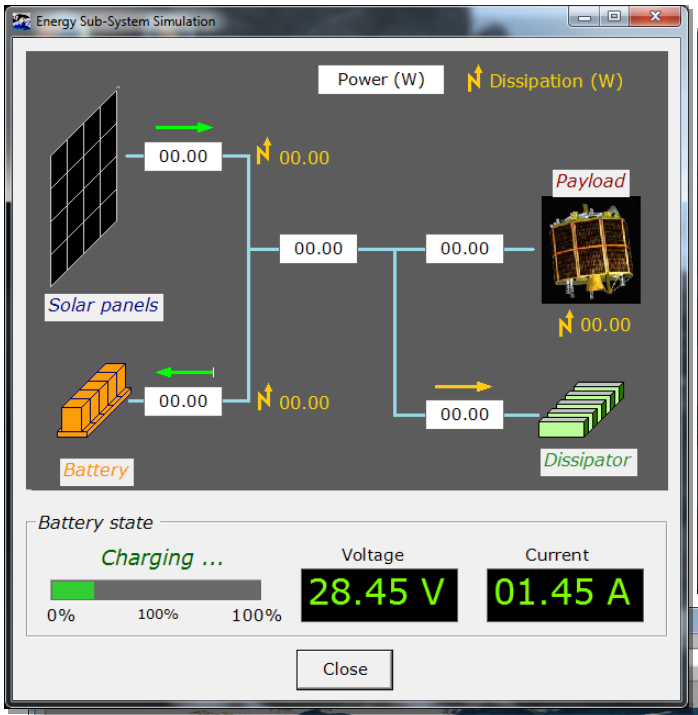
1. Objects Creation
   - Satellites
   - Ground stations
   - Links
2. Analysis
   - Ephemeris
   - Manoeuvres
   - Coverage
   - Access
   - RF Links
   - Attitude

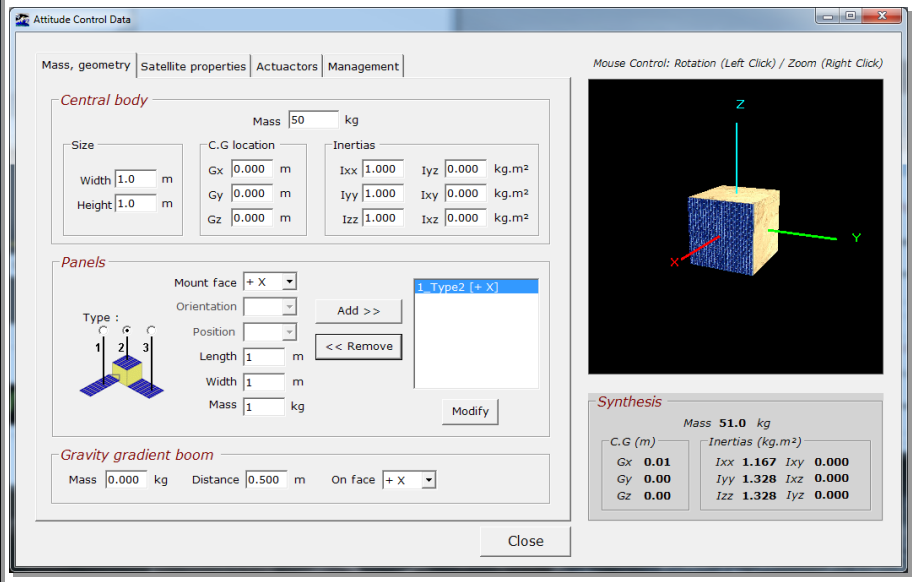
Intuitive GUI

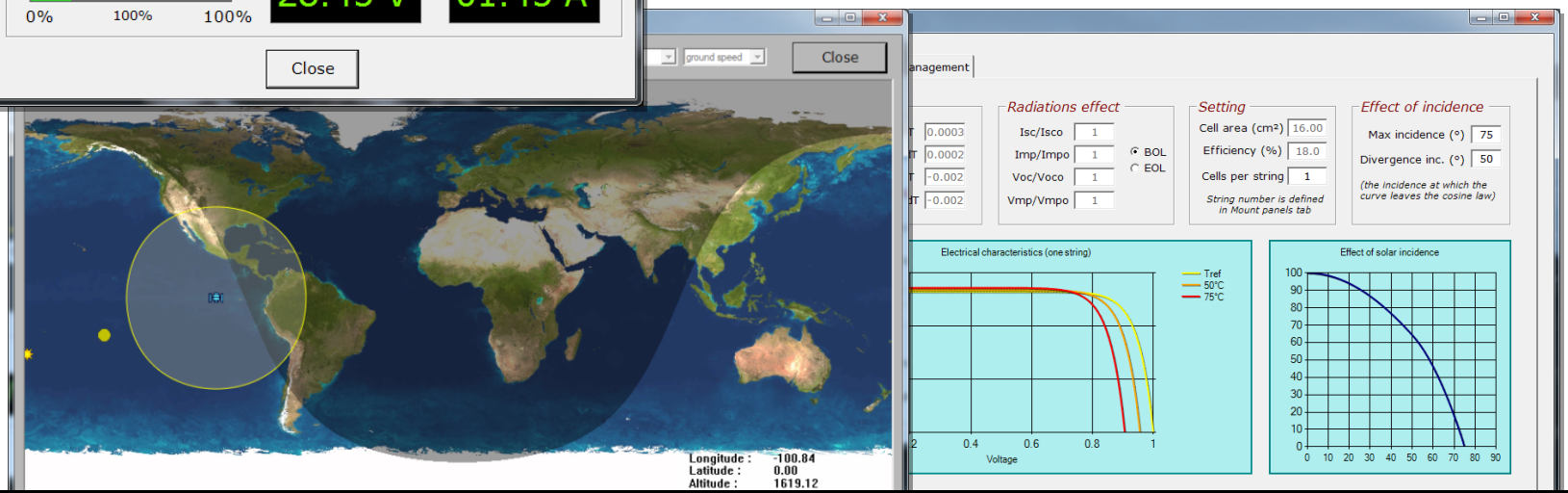
- Adapted to students



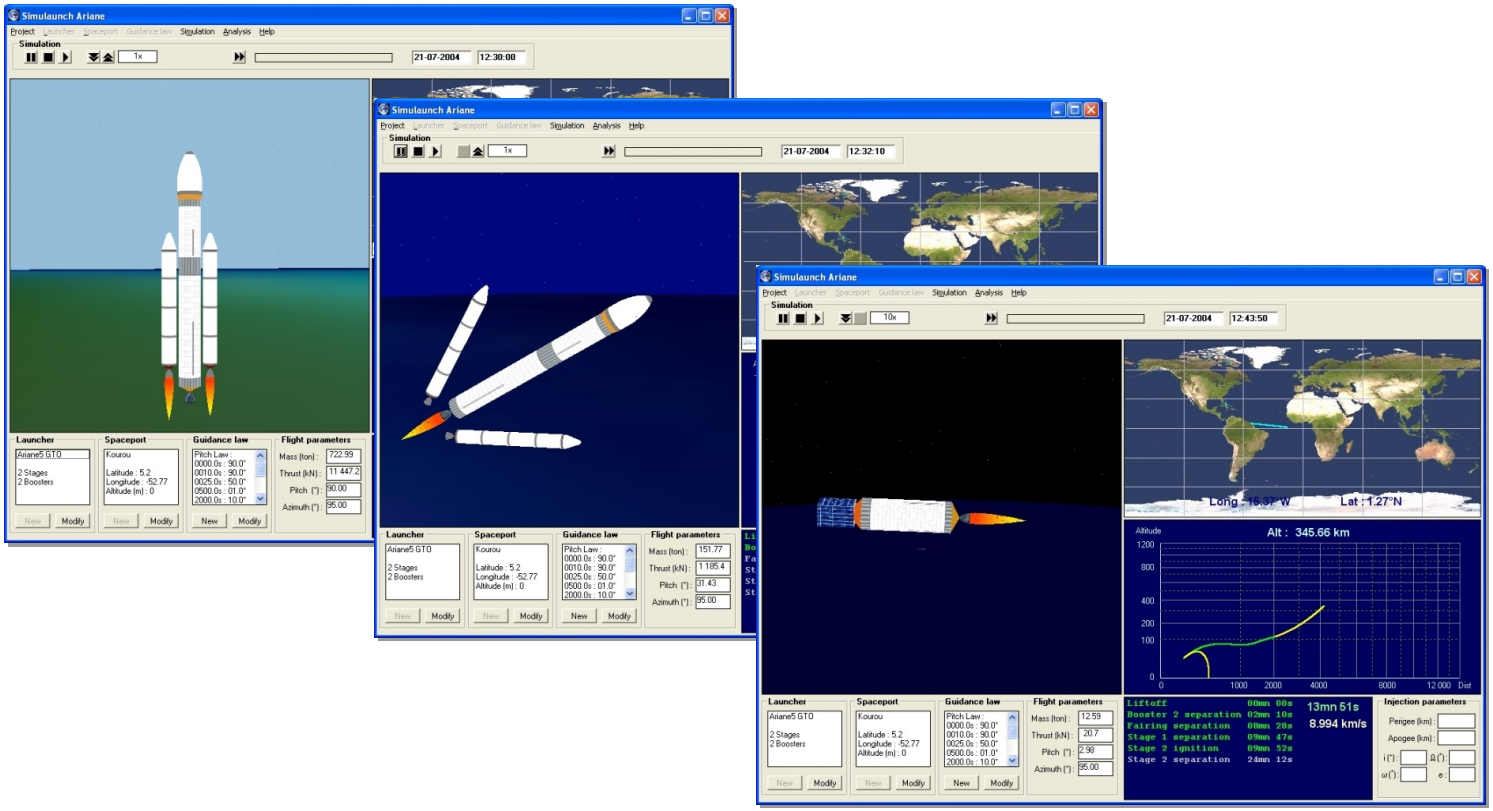
Simusat


Energy Sub-System Simulation
Power (W)
Dissipation (W)
00.00
00.00
00.00
00.00
00.00
00.00
00.00
Payload
Solar panels
Battery
Dissipator
Battery state
Charging ...
0%
100%
100%
Voltage
28.45 V
Current
01.45 A
Close


Attitude Control Data
Mass, geometry
Satellite properties
Actuactors
Management
Mouse Control: Rotation (Left Click) / Zoom (Right Click)
Central body
Mass 50 kg
Size
Width 1.0 m
Height 1.0 m
C.G location
Gx 0.000 m
Gy 0.000 m
Gz 0.000 m
Inertias
Ixx 1.000 Iyz 0.000 kg.m²
Iyy 1.000 Ixy 0.000 kg.m²
Izz 1.000 Ixz 0.000 kg.m²
Panels
Mount face + X
Orientation
Position
Length 1 m
Width 1 m
Mass 1 kg
Type :
Add >>
<< Remove
1_Type2 [+ X]
Modify
Gravity gradient boom
Mass 0.000 kg
Distance 0.500 m
On face + X
Synthesis
Mass 51.0 kg
C.G (m)
Gx 0.01
Gy 0.00
Gz 0.00
Inertias (kg.m²)
Ixx 1.167 Ixy 0.000
Iyy 1.328 Ixz 0.000
Izz 1.328 Iyz 0.000
Close


ground speed
Close
Longitude : -100.84
Latitude : 0.00
Altitude : 1619.12
Radiations effect
Isc/Isco 1
Imp/Impo 1
Voc/Voco 1
Vmp/Vmpo 1
BOL
EOL
Setting
Cell area (cm²) 16.00
Efficiency (%) 18.0
Cells per string 1
String number is defined in Mount panels tab
Effect of incidence
Max incidence (°) 75
Divergence inc. (°) 50
(the incidence at which the curve leaves the cosine law)
Electrical characteristics (one string)
Tref
50°C
75°C
Voltage
Effect of solar incidence

Simulaunch


Simulaunch Ariane
Project Launcher Spaceport Guidance law Simulation Analysis Help
Simulation
21-07-2004
12:30:00
Launcher
Spaceport
Guidance law
Flight parameters
Simulaunch Ariane
21-07-2004
12:32:10
Simulaunch Ariane
21-07-2004
12:43:50
Long : 16.37° W
Lat : 1.27° N
Alt : 345.66 km
Liftoff 00mn 00s
Booster 2 separation 02mn 10s
Fairing separation 08mn 20s
Stage 1 separation 09mn 47s
Stage 2 ignition 09mn 52s
Stage 2 separation 24mn 12s
13mn 51s
8.994 km/s
Injection parameters

Kerbal Space Program before Kerbal Space Program...

ISAE-SUPAERO Software Legacy

Pros: Homemade

- Fit exactly to ISAE-SUPAERO needs
- Adapt what we want
- No intellectual property issue
- Short dev cycles

Cons: Homemade

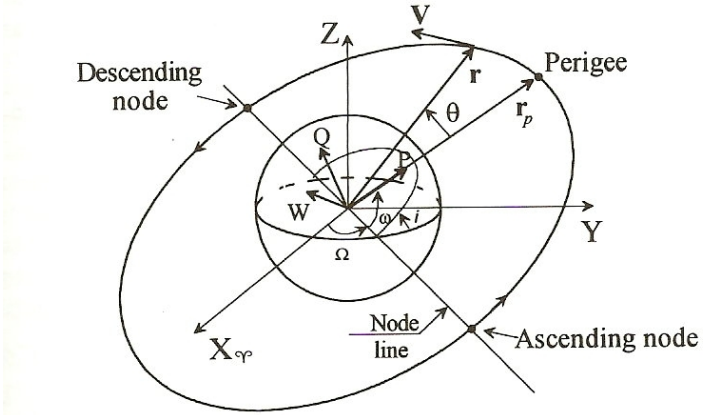
- Not open-source, no community behind
- Costful for internal developpers
- Not cross platform
- Validation by hand

Create the germ of JSatOrb, a version of SatOrb in Java

Student-focused learning tool

Professional software for researchers

Implement a clear division in the coding



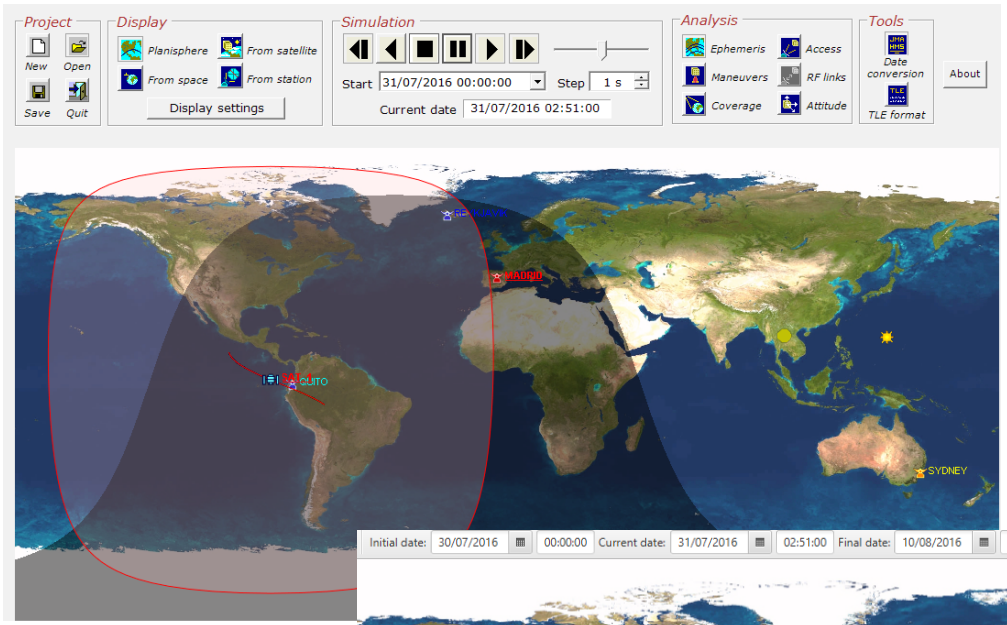
Calculations

User interface

Choosing an Astrodynamics Library

Feature type	Software / Features	SatOrb	OreKit	JAT	TUDAT	CelestLab
Visualization	Terminal	✓	✓	✓	✓	✓
	2D (planisphere)	✓	-	✓	-	✓
	3D (Earth)	✓	-	✓	-	-
Ephemeris	Position/Velocity	✓	✓	✓	✓	✓
	Keplerian Parameters	✓	✓	✓	✓	✓
	Eclipses	✓	✓	✓	✓	✓
Manoeuvres	Impulse	✓	✓	✓	✓	✓
	Continuous	-	✓	✓	✓	✓
Time	UTC	✓	✓	✓	✓	✓
	TAI	-	✓	✓	✓	✓
	Julian	✓	✓	✓	✓	✓
	NORAD	✓	-	-	-	-
Propagators	Kepler	✓	✓	✓	✓	✓
	Brouwer	✓	-	-	-	-
	Mosaif	✓	-	-	-	-
	SGP4/SDP4	✓	✓	✓	-	-
	Central	-	✓	✓	-	✓
	Lyddane	-	-	-	-	✓
	Eckstein-Hescher	-	✓	✓	-	✓
	Cohessy Wiltshire	-	-	✓	✓	✓
Others	TLE Format	✓	✓	✓	✓	✓
	Coverage	✓	✓	✓	-	✓
	Constellations	✓	-	-	-	-
	Ground stations	✓	✓	✓	✓	✓
	Links	✓	-	-	-	-
	Language	VisualBasic	Java	Java	C++	Scilab

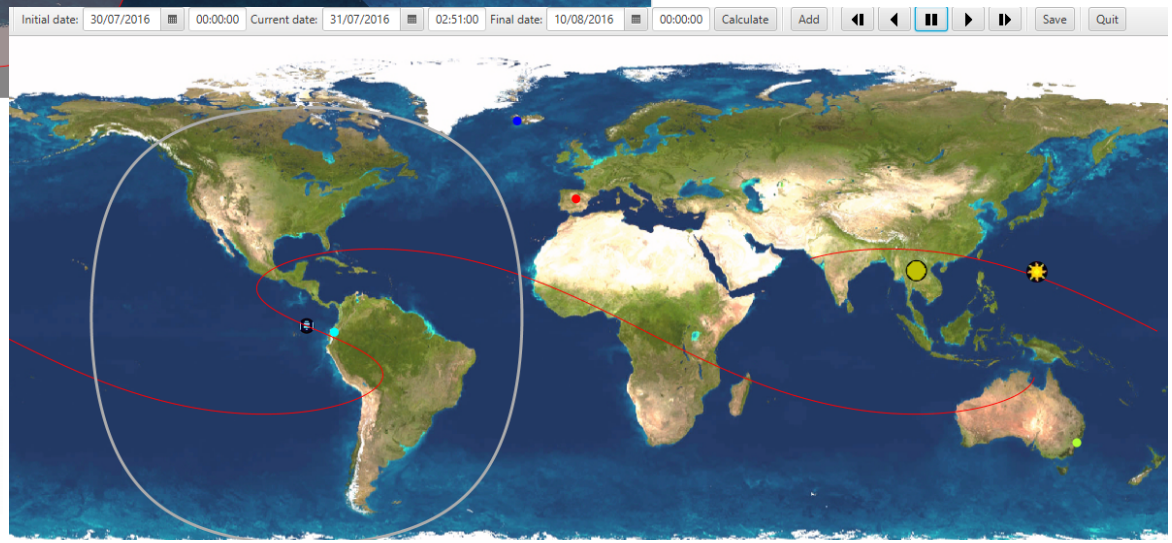
JSatorb: Full Java solution ? - JavaFX version



From Satorb...

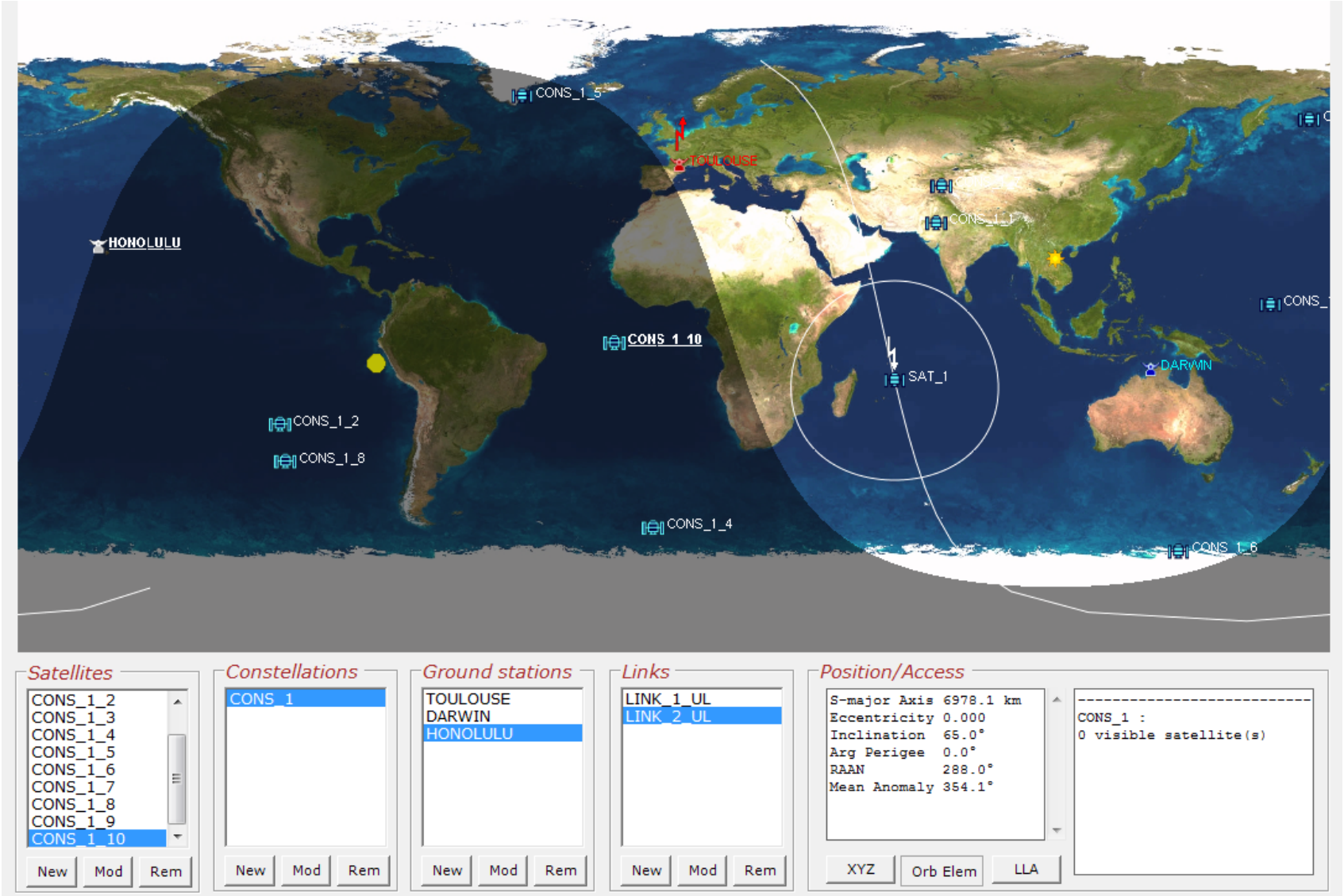
Microsoft VB.net

... To JSatorb



Orekit

Java


CONS_1_5
TOULOUSE
HONOLULU
CONS_1_10
SAT_1
DARWIN
CONS_1_2
CONS_1_8
CONS_1_4
CONS_1_6
Satellites
CONS_1_2
CONS_1_3
CONS_1_4
CONS_1_5
CONS_1_6
CONS_1_7
CONS_1_8
CONS_1_9
CONS_1_10
New
Mod
Rem
Constellations
CONS_1
New
Mod
Rem
Ground stations
TOULOUSE
DARWIN
HONOLULU
New
Mod
Rem
Links
LINK_1_UL
LINK_2_UL
New
Mod
Rem
Position/Access
S-major Axis 6978.1 km
Eccentricity 0.000
Inclination 65.0°
Arg Perigee 0.0°
RAAN 288.0°
Mean Anomaly 354.1°
XYZ
Orb Elem
LLA
CONS_1 :
0 visible satellite(s)

What about modularity?

Pros

- Fast to setup
- Fully Java oriented
- Classical testing/validation process
- Known territory...

Cons

- One heavy client
- Fully Java oriented
  - How to adapt it with other libraries?
  - Dependencie to the JVM...
- Still a heavy development process

Why developping "JSatorb"?

- Satorb

Pros: Homemade

- Fit already with our needs
- Years of support XP on it

Cons: Monolithic block

- Huge validation to do
- Not cross platform
- Data flow interface
- Not standardized

- JSatorb

Cons: New Soft

- Development Effort
- Architecture evolution

Pros: Linked to the world

- Cross-plateform
- Modularity
- Long term compatibility
- Using "real" Astrodynamic libraries

Switching to a Service Oriented Architecture

Web oriented architecture

- Front-end for the user interface
- Back-end for the calculus stuff

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Advantage

- Modularity (components oriented, user interface separated)
- Portability (browser)

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Web oriented architecture

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- Back-end for the calculus stuff

Advantage

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- Portability (browser)

Limits

- Wide implementation choices to do
- Re-do it all!

What's a REST API?

REST: REpresentational State Transfer

1. Based on HTTP but **not** a standard:
   - Respect of conventions
   - Good practices

https://www.ics.uci.edu~fielding/pubs/dissertation/rest_arch_style.htm

What's a REST API?

REST: REpresentational State Transfer

1. Based on HTTP but **not** a standard:
   - Respect of conventions
   - Good practices
2. Five rules:
   - URI as ressource identifier
   - HTTP verbs as operation identifier
   - HTTP response as a ressource representation
   - links as relations between ressources
   - a parameter as an authentification token

https://www.ics.uci.edu~fielding/pubs/dissertation/rest_arch_style.htm

What's a REST API?

Rule 1: URI as ressource identifier

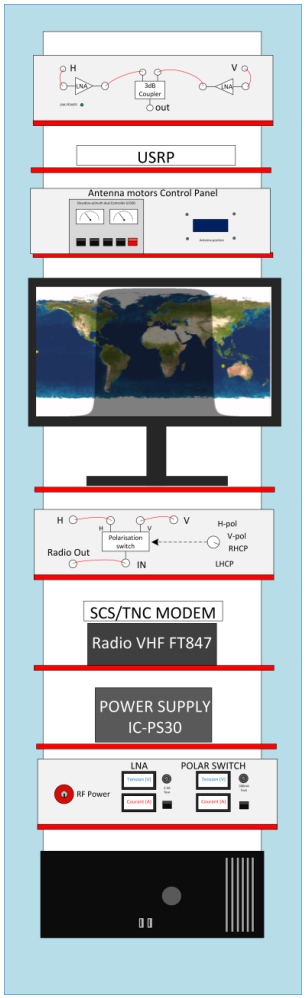
- ~~http://mywebsite.com/book~~
- http://mywebsite.com/books

What's a REST API?

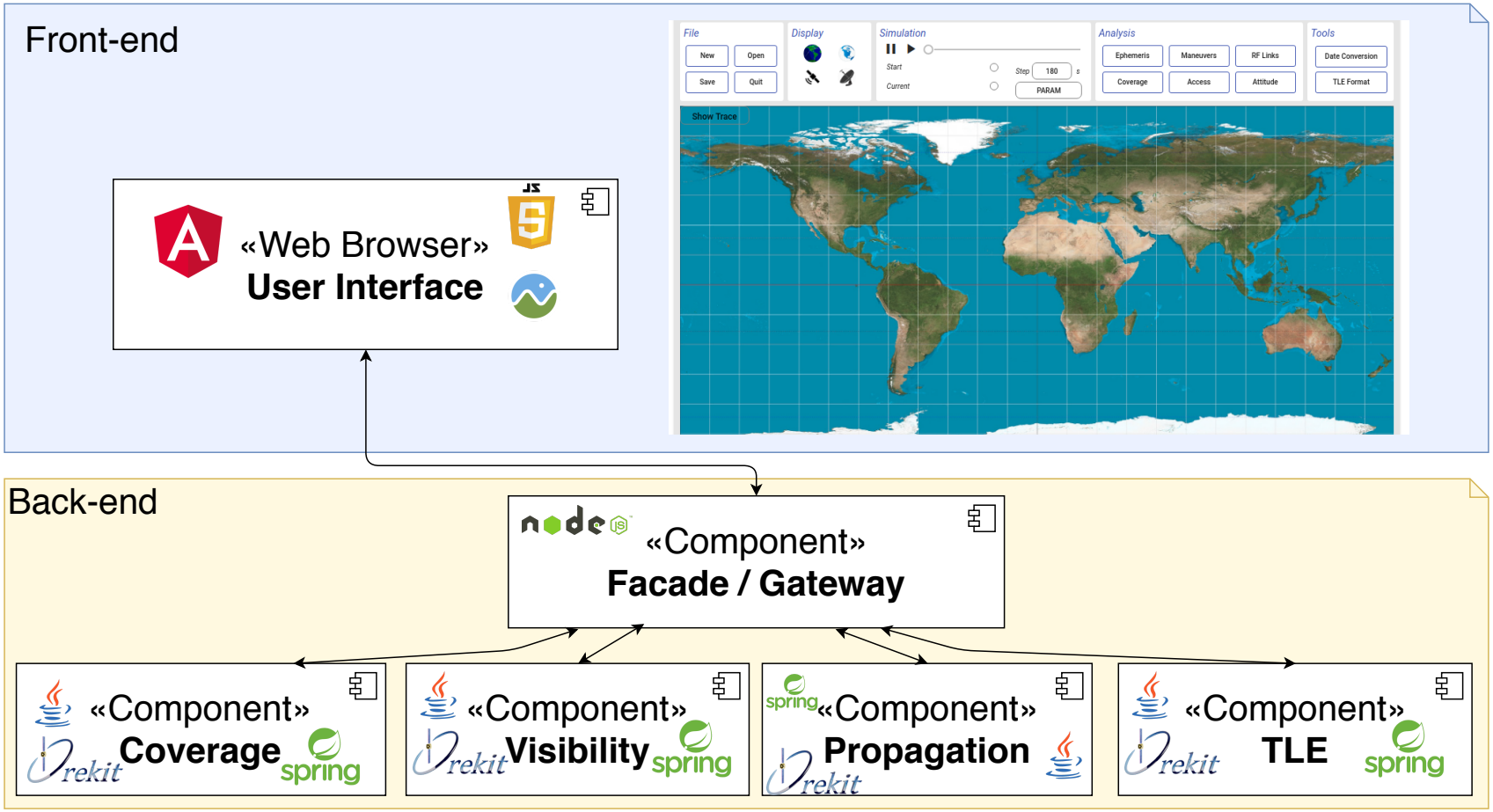
Rule 1: URI as ressource identifier

- ~~http://mywebsite.com/books/comments/87~~
- http://mywebsite.com/books/87/comments

Our Current Operating Ground Station (SCC)

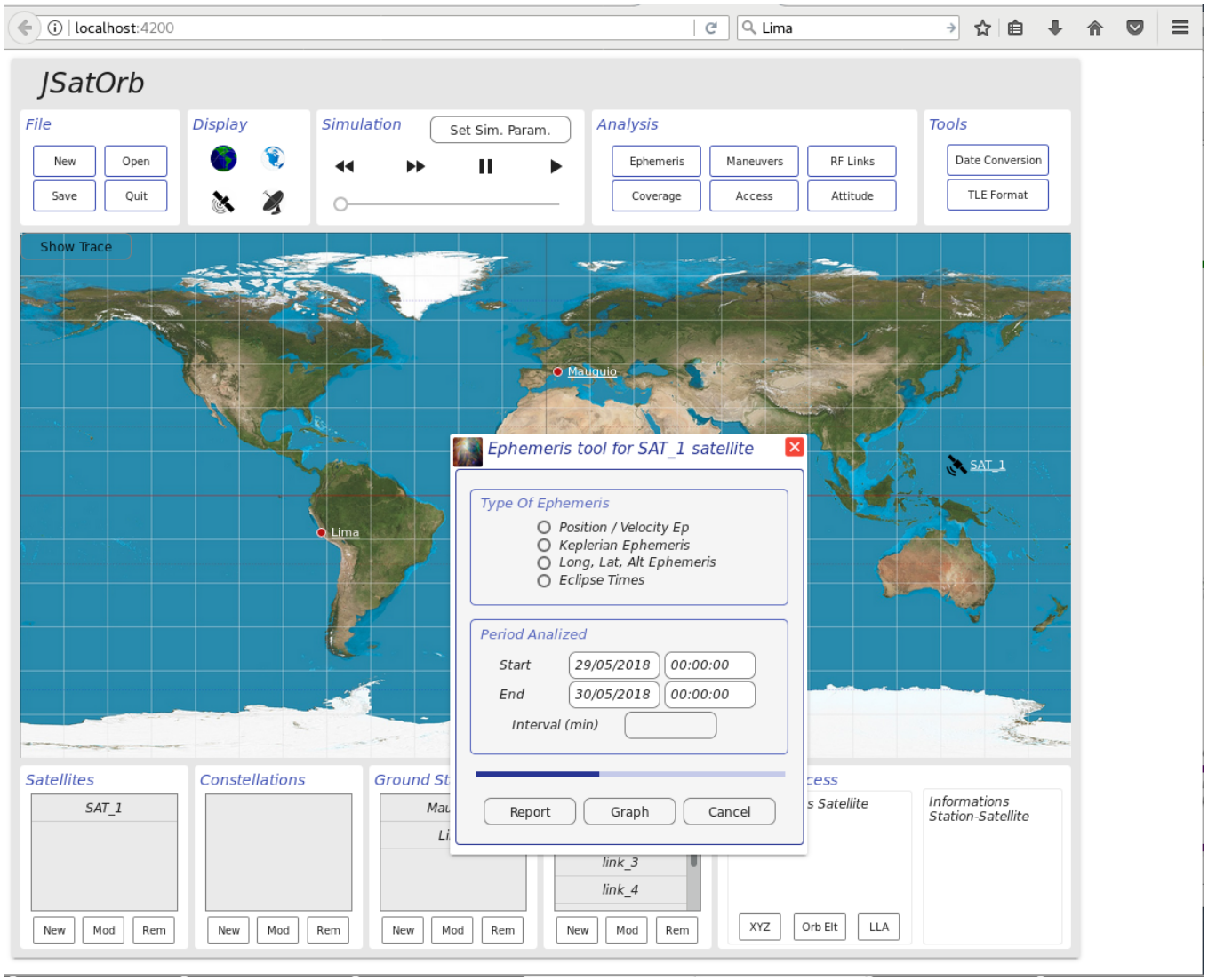


JSatorb: Service Oriented Architecture

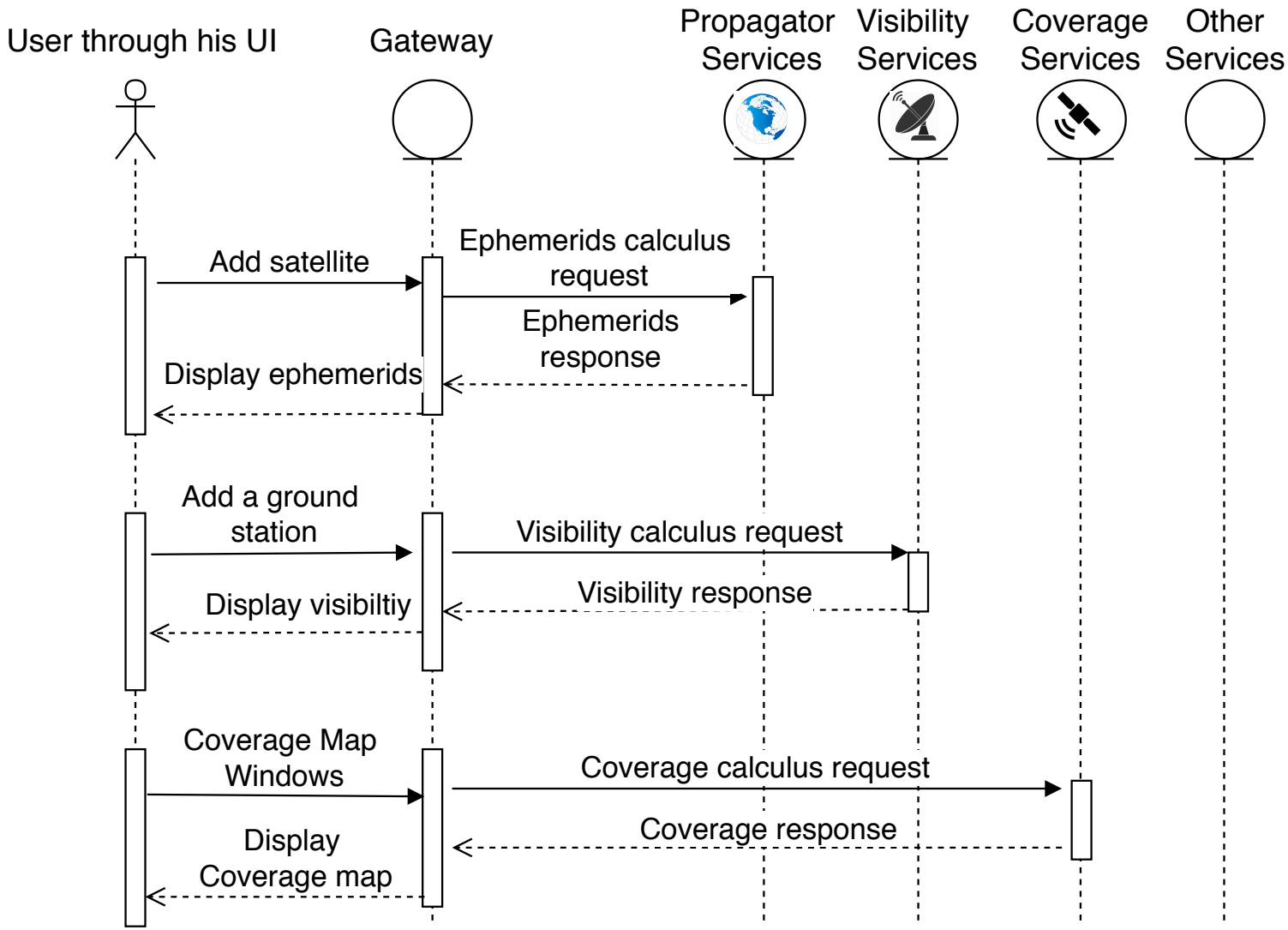


Text

Frontend development: Theo Koudlansky



JSatorb: Typical Use Case Scenario



Nowadays academics requirements

- Open-Source
- Cross-platform
- Standardized
- Documented

Take home Message

- Still cover **teachings** requirements
- Still allow customization for **research**
- Intercompatibility - Input/Outputs Standardization
- Open-Source under MIT licence
  (`https://sourceforge.isae.fr/projects/jsatorb/repository`)

Thank you for your attention !

Any question ?