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Luplink, an Open Source Web Application for an Ergonomic Link Budget Analysis

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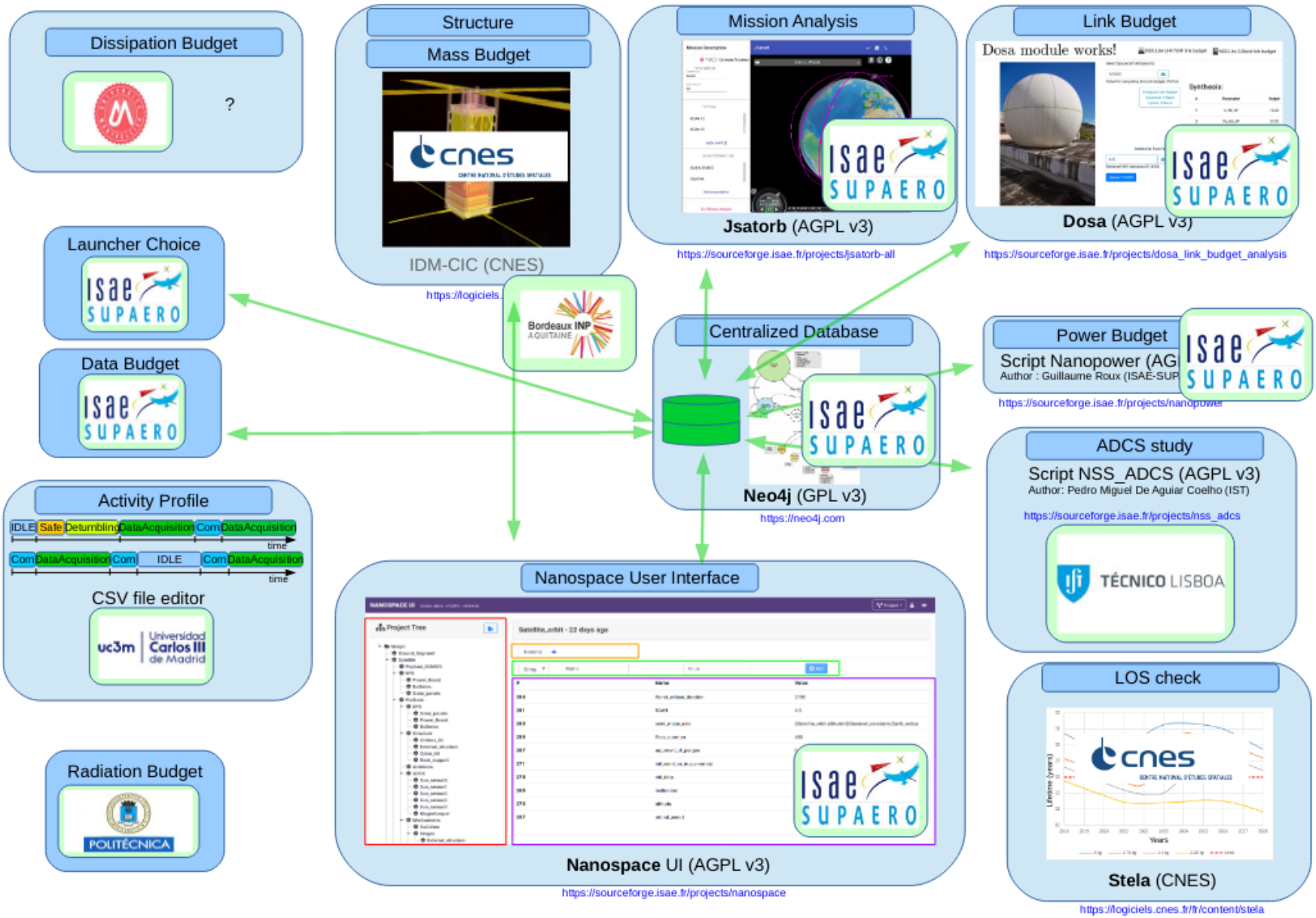
Outline

NSS, JSatorb & Luplink : some context



NSS, JSatorb & Luplink : some context

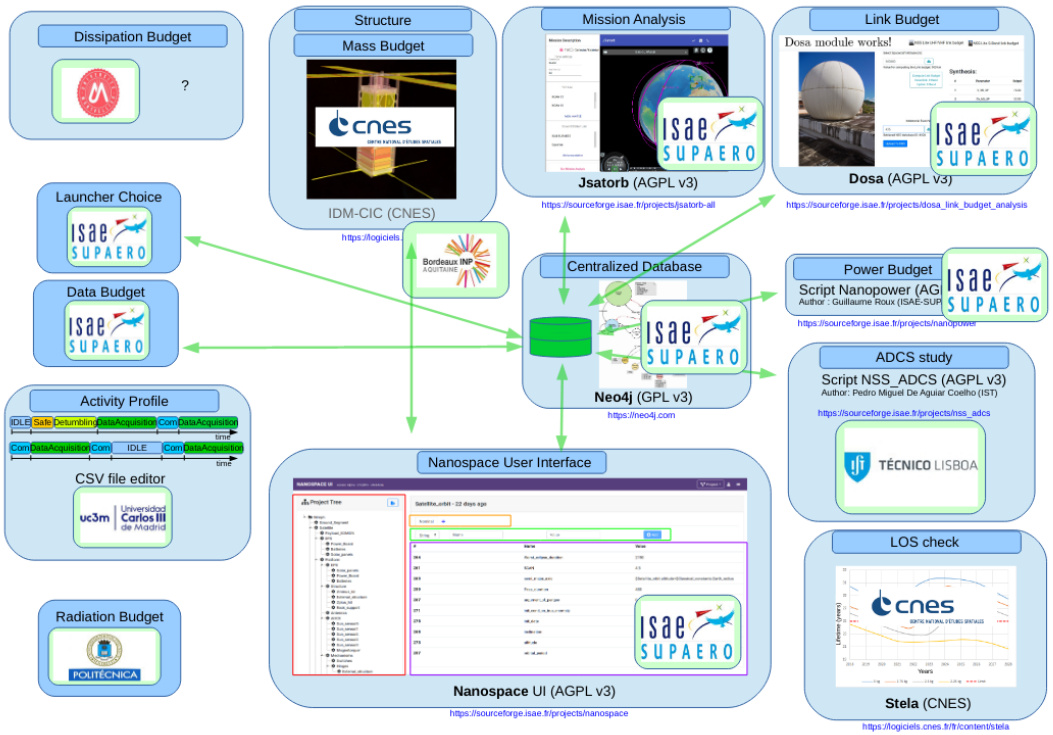


Figure: Nanostar

Luplink

Open-source tool integrated inside JSatOrb.

Requirements :

- Usable within NSS
- Suitable for teaching
- Modular
- Unit-tested

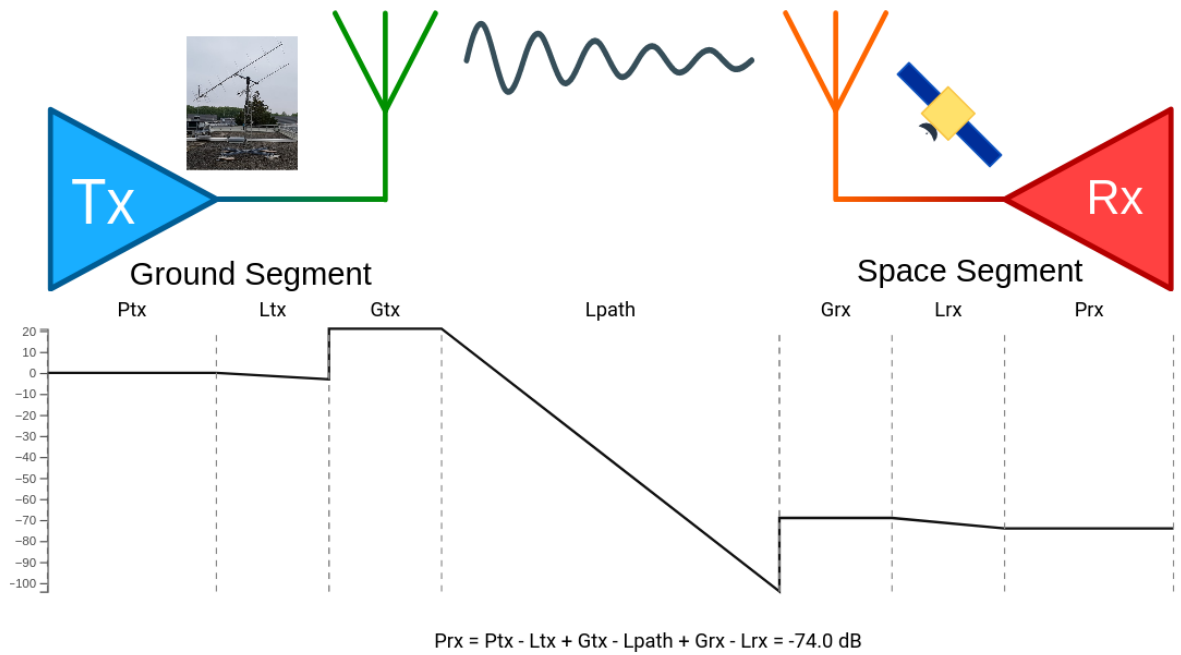
Outline

How to compute link budgets?

Link Budget ?

$$P_{received}(dB) = P_{transmitted}(dB) + G_{dB} - L_{dB}$$

Losses : FSL, antenna depointing, polarization, edge of coverage, technological, rain attenuation, ...



State of the art

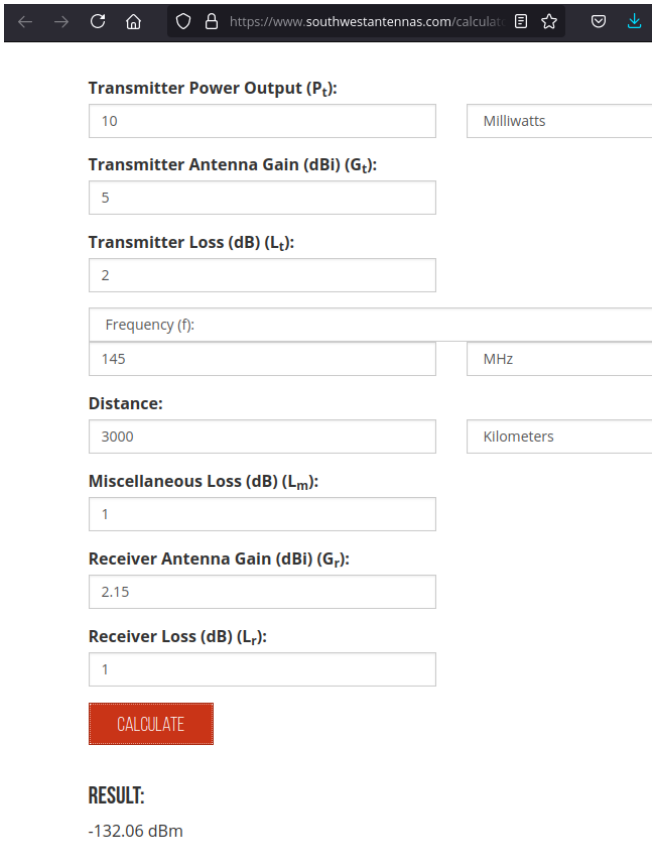


Figure: southwestantennas.com

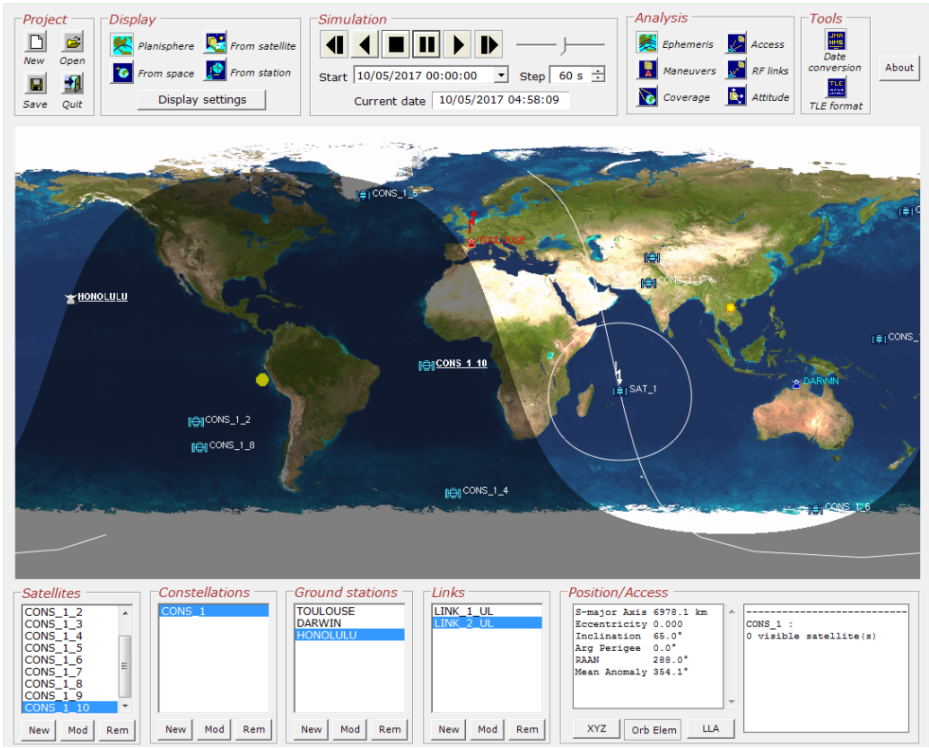
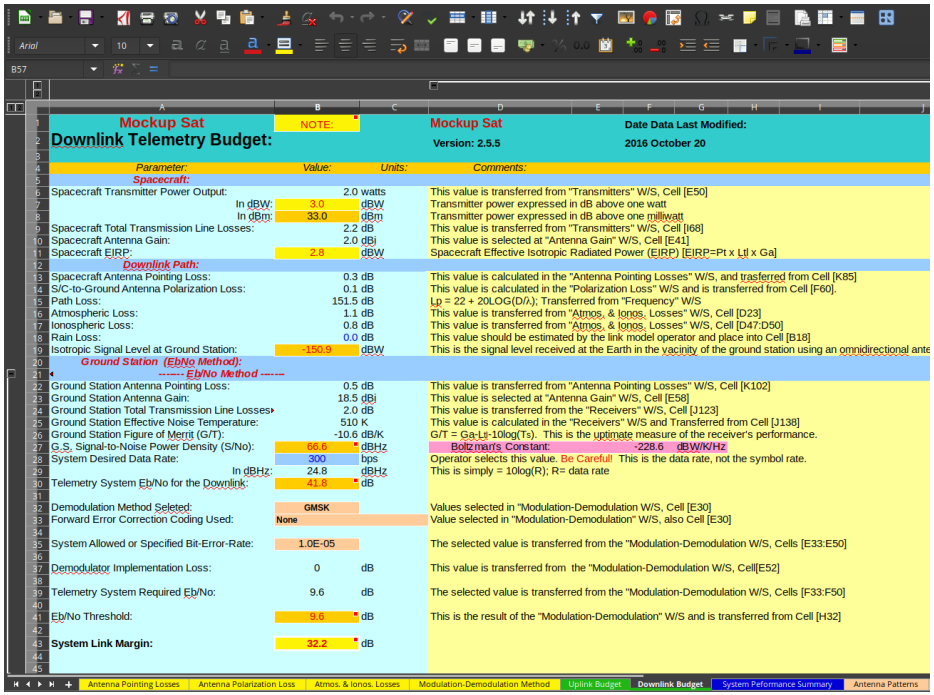


Figure: Satorb

State of the art



Mockup Sat	NOTE:		Mockup Sat	Date Data Last Modified:
Downlink Telemetry Budget:			Version: 2.5.5	2016 October 20
Parameter:	Value:	Units:	Comments:	
Spacecraft:				
Spacecraft Transmitter Power Output:		2.0 watts	This value is transferred from "Transmitters" W/S, Cell [E50]	
In dBW:	3.0	dBW	Transmitter power expressed in dB above one watt	
In dBm:	33.0	dBm	Transmitter power expressed in dB above one milliwatt	
Spacecraft Total Transmission Line Losses:		2.2 dB	This value is transferred from "Transmitters" W/S, Cell [I68]	
Spacecraft Antenna Gain:		2.0 dBi	This value is selected at "Antenna Gain" W/S, Cell [E41]	
Spacecraft EIRP:	2.8	dBW	Spacecraft Effective Isotropic Radiated Power (EIRP) [EIRP=Pt x Ltl x Ga]	
Downlink Path:				
Spacecraft Antenna Pointing Loss:		0.3 dB	This value is calculated in the "Antenna Pointing Losses" W/S, and trasferred from Cell [K85]	
S/C-to-Ground Antenna Polarization Loss:		0.1 dB	This value is calculated in the "Polarization Loss" W/S and is transferred from Cell [F60].	
Path Loss:		151.5 dB	Lp = 22 + 20LOG(D/λ); Transferred from "Frequency" W/S	
Atmospheric Loss:		1.1 dB	This value is transferred from "Atmos. & Ionos. Losses" W/S, Cell [D23]	
Ionospheric Loss:		0.8 dB	This value is transferred from "Atmos. & Ionos. Losses" W/S, Cell [D47:D50]	
Rain Loss:		0.0 dB	This value should be estimated by the link model operator and place into Cell [B18]	
Isotropic Signal Level at Ground Station:	-150.9	dBW	This is the signal level received at the Earth in the vacinity of the ground station using an omnidirectional ante	
Ground Station (Eb/No Method):				
------ Eb/No Method ------				
Ground Station Antenna Pointing Loss:		0.5 dB	This value is transferred from "Antenna Pointing Losses" W/S, Cell [K102]	
Ground Station Antenna Gain:		18.5 dBi	This value is selected at "Antenna Gain" W/S, Cell [E58]	
Ground Station Total Transmission Line Losses:		2.0 dB	This value is transferred from the "Receivers" W/S, Cell [J123]	
Ground Station Effective Noise Temperature:		510 K	This value is calculated in the "Receivers" W/S and Transferred from Cell [J138]	
Ground Station Figure of Merrit (G/T):		-10.6 dB/K	G/T = Ga-Ll-10log(Ts). This is the uptimate measure of the receiver's performance.	
G.S. Signal-to-Noise Power Density (S/No):	66.6	dBHz	Boltzmann's Constant: -228.6 dBW/K/Hz	
System Desired Data Rate:	300	bps	Operator selects this value. Be Carefull This is the data rate, not the symbol rate.	
In dBHz:	24.8	dBHz	This is simply = 10log(R); R= data rate	
Telemetry System Eb/No for the Downlink:	41.8	dB		
Demodulation Method Seleted:	GMSK		Values selected in "Modulation-Demodulation W/S, Cell [E30]	
Forward Error Correction Coding Used:	None		Value selected in "Modulation-Demodulation" W/S, also Cell [E30]	
System Allowed or Specified Bit-Error-Rate:	1.0E-05		The selected value is transferred from the "Modulation-Demodulation W/S, Cells [E33:E50]	
Demodulator Implementation Loss:	0	dB	This value is transferred from the "Modulation-Demodulation W/S, Cell[E52]	
Telemetry System Required Eb/No:	9.6	dB	The selected value is transferred from the "Modulation-Demodulation W/S, Cells [F33:F50]	
Eb/No Threshold:	9.6	dB	This is the result of the "Modulation-Demodulation" W/S and is transferred from Cell [H32]	
System Link Margin:	32.2	dB		

Antenna Pointing Losses | Antenna Polarization Loss | Atmos. & Ionos. Losses | Modulation-Demodulation Method | Uplink Budget | Downlink Budget | System Peformance Summary | Antenna Patterns

Figure: AMSAT spreadsheet

Python libraries

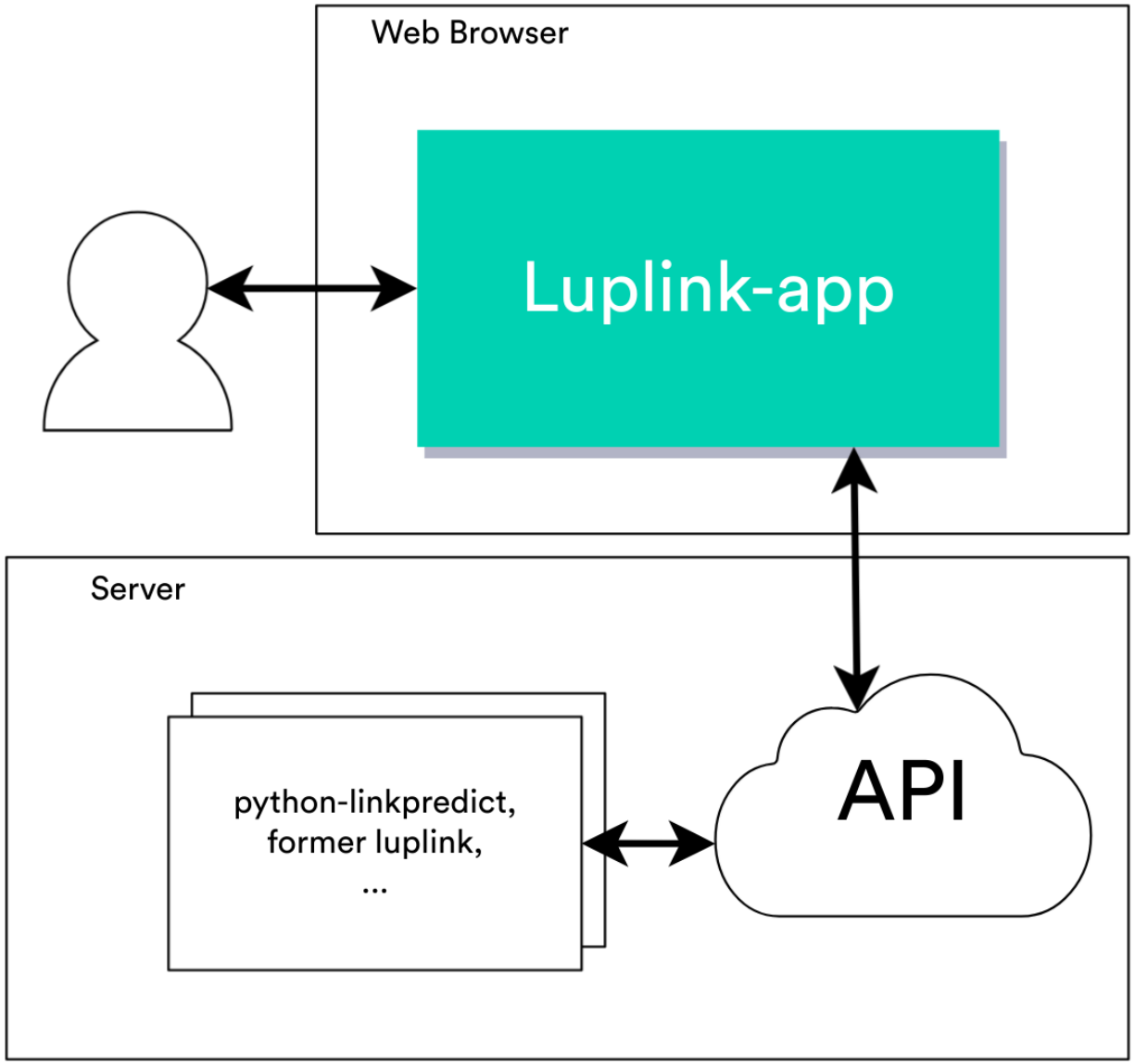
Python libraries :

- linkpredict [1]
- luplink
- ...

[1] https://gitlab.com/librecube/lib/python-linkpredict

Outline

Standalone version



Standalone version

Luplink Diagram Simple Link Budget Full Link Budget Untitled_Link_Budget Compute

GEOMETRY UPLINK DOWNLINK RESULT

Welcome

LINK BUDGET

Geometry

Uplink

Carrier & Environment

Transmitter

Receiver

Downlink

Carrier & Environment

Transmitter

Receiver

Results

v0.2.0

Uplink Carrier

Frequency: 146 MHz

Bandwidth: 3 Hz

Bit Rate: 1200 bps

Eb/N0 Threshold: 23.2 dB

Implementation Loss: -1 dB

System Margin: 10 dB

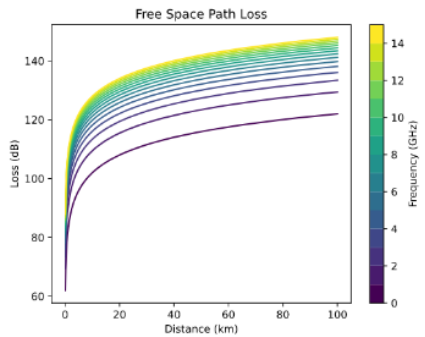
Atmosphere

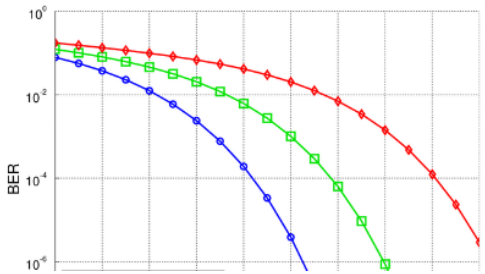
Depointing Loss: -0.9 dB

Documentation

Carrier & Environment

Here we can define the carrier used for the uplink. The Free Space Path Loss (FSPL) and atmospheric losses depend on frequency but also polarization of the carrier. This graph shows the losses in dB due to propagation in free space as a function of distance between antennas and frequency of the carrier



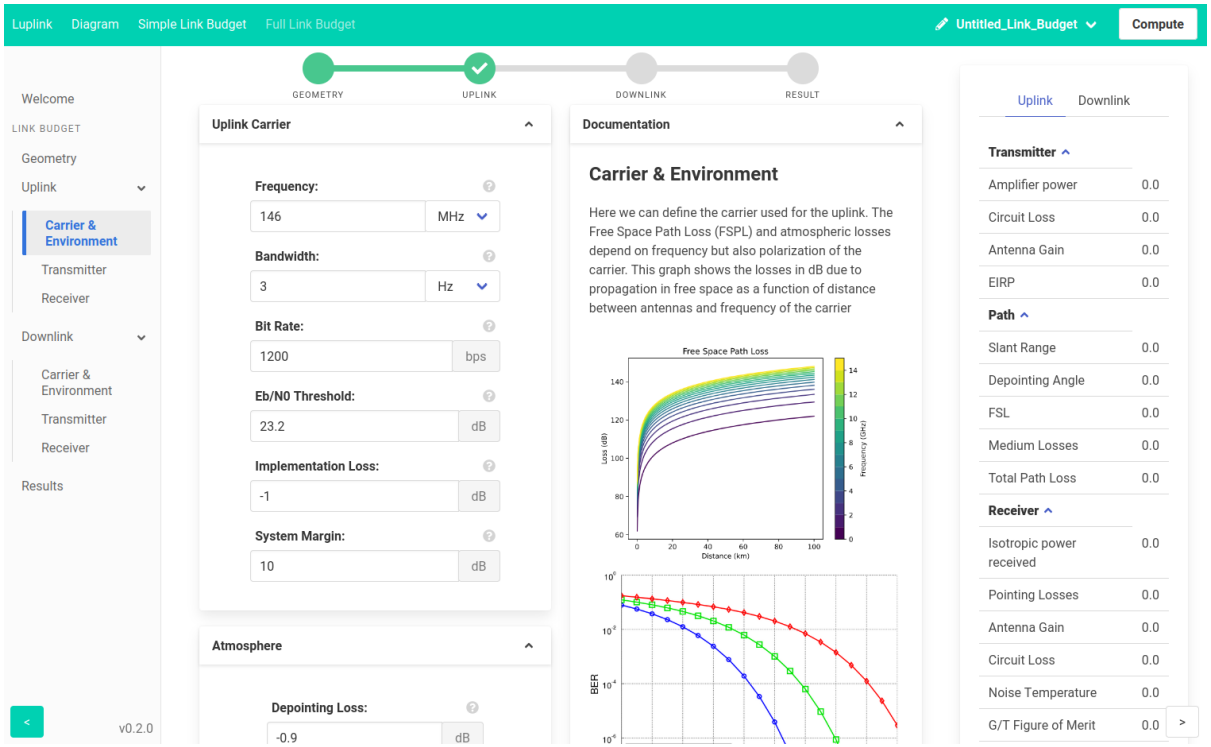


Uplink Downlink

Transmitter	
Amplifier power	0.0
Circuit Loss	0.0
Antenna Gain	0.0
EIRP	0.0
Path	
Slant Range	0.0
Depointing Angle	0.0
FSL	0.0
Medium Losses	0.0
Total Path Loss	0.0
Receiver	
Isotropic power received	0.0
Pointing Losses	0.0
Antenna Gain	0.0
Circuit Loss	0.0
Noise Temperature	0.0
G/T Figure of Merit	0.0

https://gitlab.isae-supaero.fr/jsatorb-dev/luplink

Technologies used



- Angular / TypeScript,
- Node.js
- SCSS/SASS,
- Bulma,
- D3.js
- ...

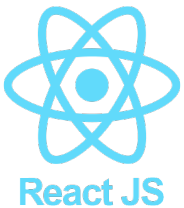
Why use a framework?

Angular framework :

- Components,
- Typescript,
- Good testing capabilities
- Used by JSatOrb (better integration)

Also linting with ESLint/Prettier

Alternatives:



Single Page Applications (SPA)

- No reload while navigating: faster load times
- Components are reusable

Standalone version

```
- FormComponent :
   * should display warnings : ok
   * should display default values : ok
   * should display custom error messages : ok
   * should display all the labels provided by parent : ok
   * should not be valid if input is not correct : ok
   * should create : ok
- SynthesisComponent :
   * should create : ok
   * should display drawing (bug) : ok
- NavbarComponent :
   * should create : ok
- NavigationSidebarComponent :
   * should create : ok
- ResultsComponent-Integration :
   * should compute and display the correct result in a reasonable amount of
   * computed results should match the AMSAT ones (downlink) : ok
   * computed results should match the AMSAT ones (uplink) : ok
- ResultsComponent :
   * should display the correct results : ok
   * should create : ok
   * should display each field only once when displaying results (bug) : ok
- CardComponent :
   * should display title : ok
   * should create : ok
   * should collapse when clicking on button : ok

Browser results:

- Chrome Headless 92.0.4515.107 (Linux x86_64): 47 tests
   - 46 ok, 1 skipped
```

Figure: ***« npm run th »*** (stands for test-headless)

README.md

Luplink: an angular link budget calculation front-end

@angular/core ^11 License AGPL v3

*This is the **main readme** for the Luplink project*

author: Julien Prissimitzis

Introduction

Luplink is an open-source front-end application for link budget calculations based on the Angular framework. The user can input multiples parameters and luplink handles calculations with its API to compute the resulting link budget.

Standalone luplink = luplink-app + API

It relies on the python-linkpredict library as a backend to handle calculations.

This project both exists as a **standalone application** and as a **library integrated inside JSatorb**

Noteworthy READMEs:

- Luplink project:
  - This file is the main readme for the luplink project
  - Luplink API's readme
- JSatorb:
  - JSatorb's readme contains instructions relevant to JSatorb installation and development
  - JSatorb-frontend's readme more specific readme about the angular fronted
- Developpers:
  - build-tools readme explains how to build luplink without hassle using docker images (there is a similar section in this readme).
  - luplink-app's readme Some angular-specific informations (useful for developpers)
  - ngx-luplink's readme is relevant to the ngx-luplink library and provided on the npmjs.com page for ngx-luplink package

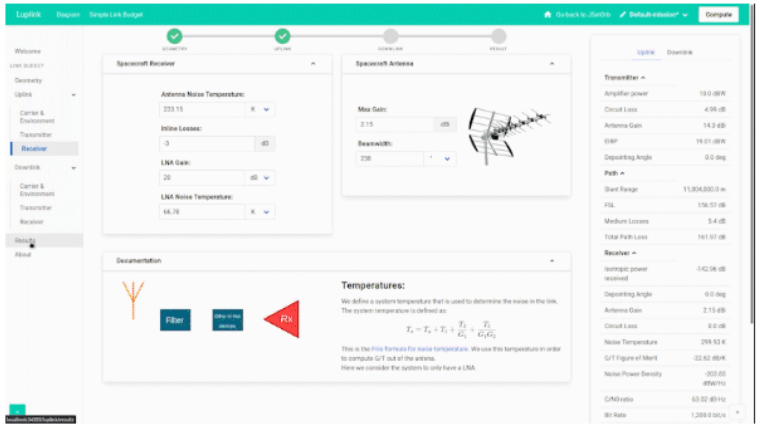


Figure: Docker containers on GitLab

Ergonomy

Some pitfalls

- User frustration
- Confusing interface

Figure: Entire books dedicated to forms

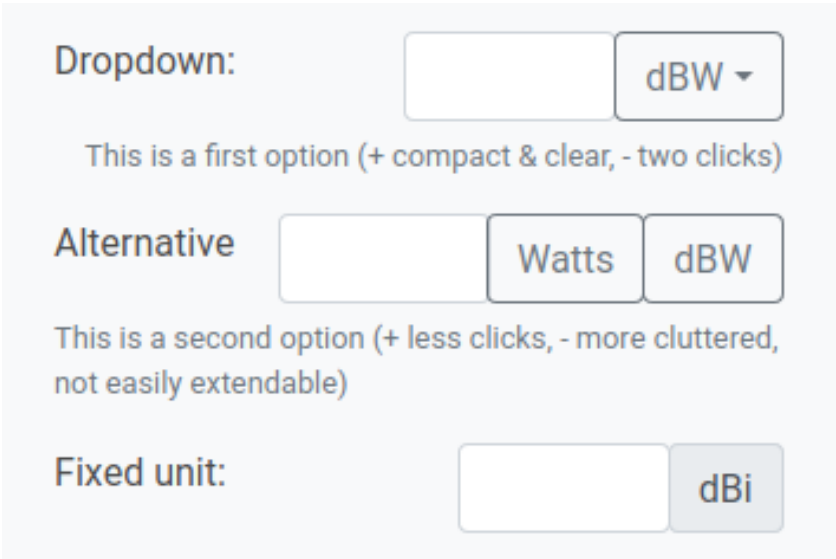


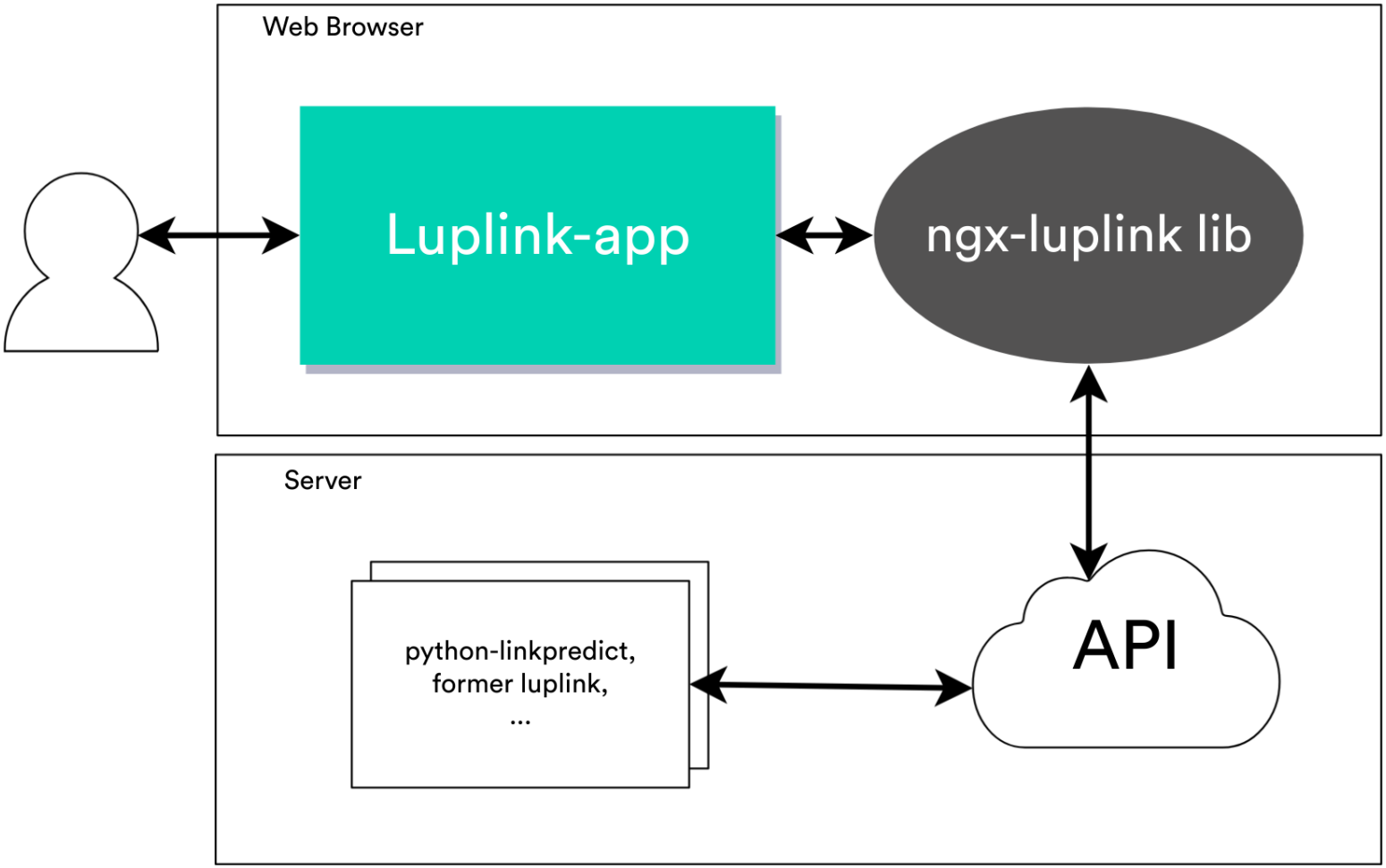
Figure: Comparing various solutions

What to keep in mind

- Accessibility
- Avoid ambiguity

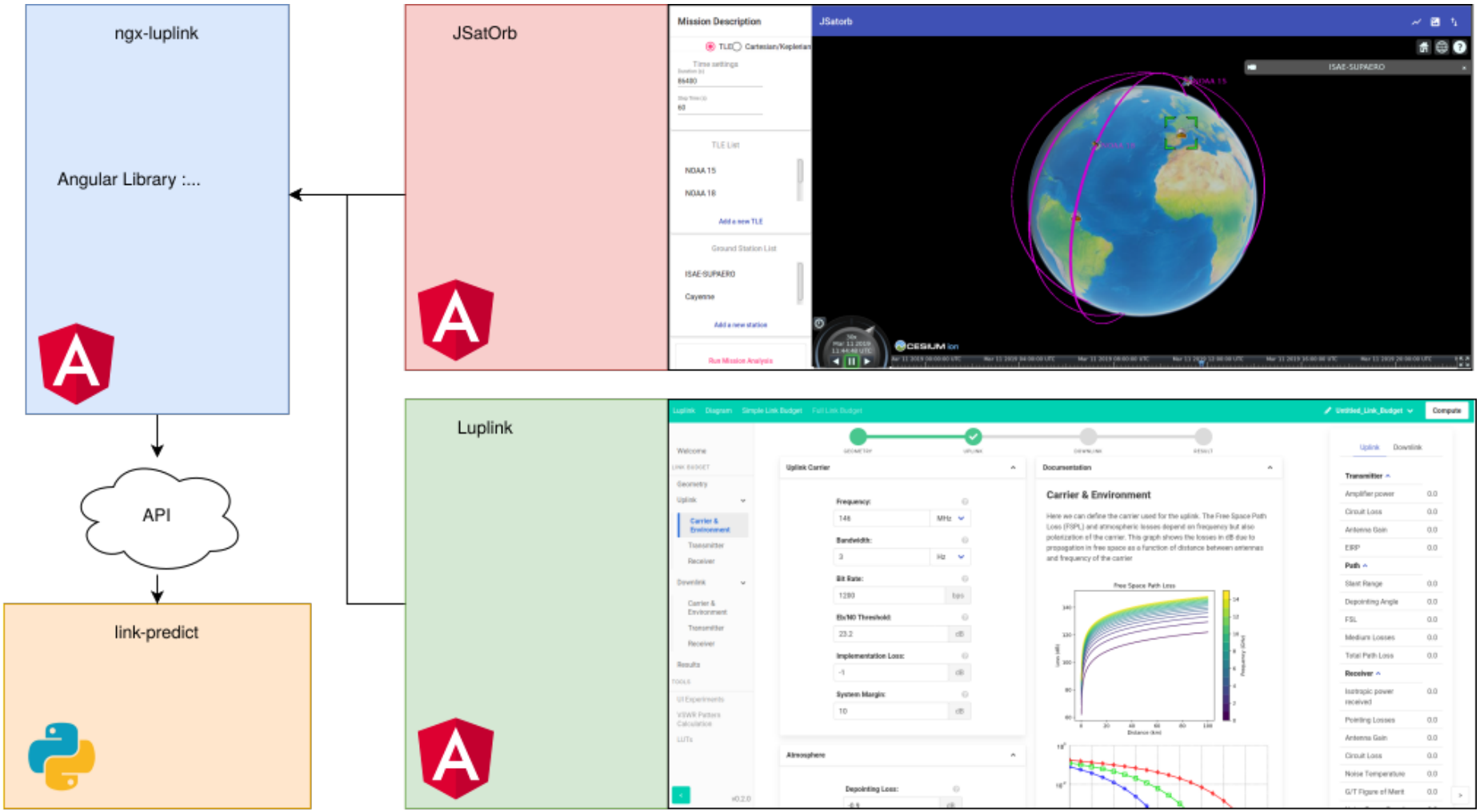
Outline

Project Architecture



https://www.npmjs.com/package/@luplink/ngx-luplink

Project Architecture

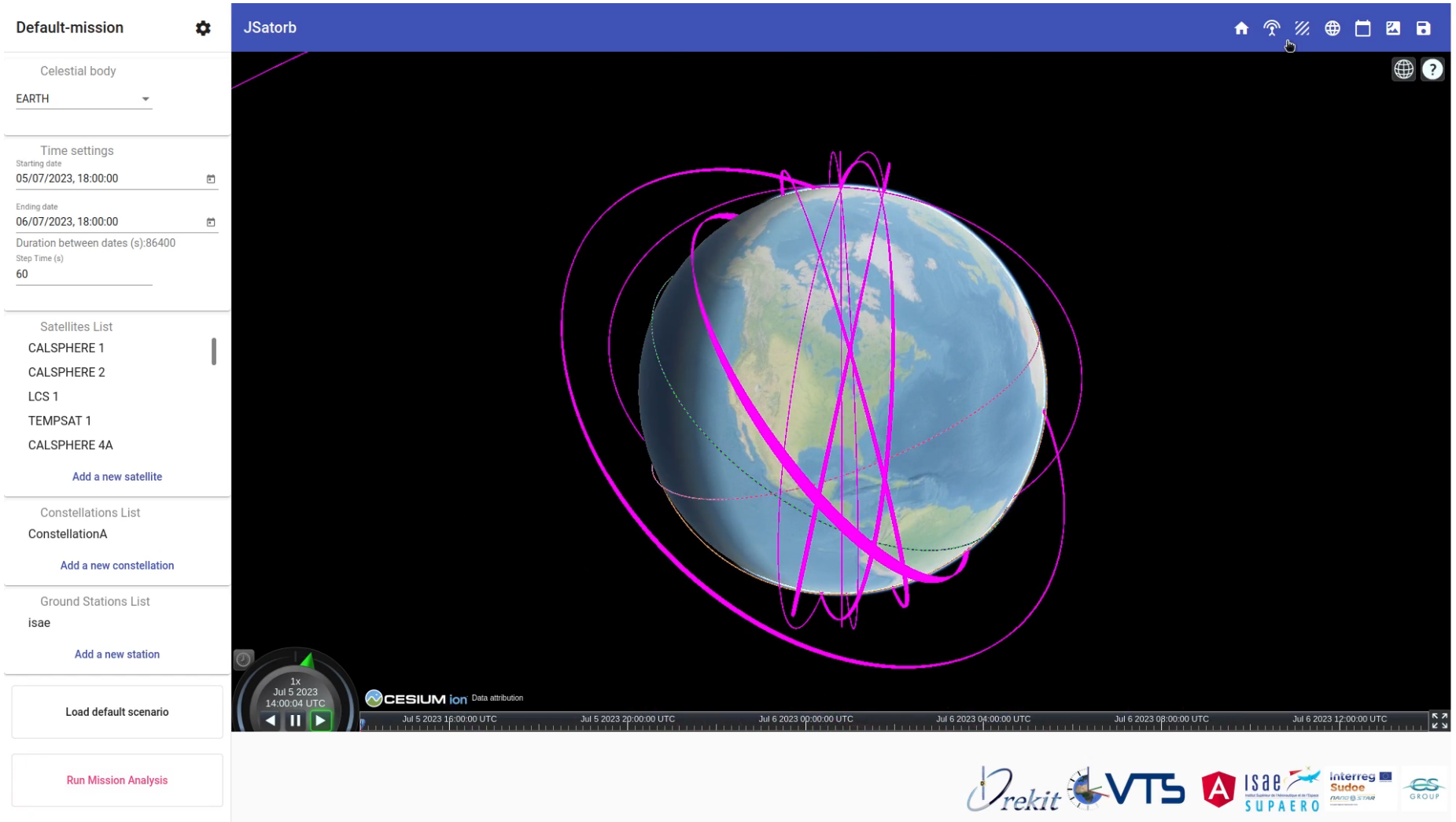


Demonstration

Video Demo

https://youtu.be/B7LMSZIIIds

Demonstration



Demonstration

Luplink Diagram Simple Link Budget — Go back to JSatOrb — Default-mission — Compute

Welcome

LINK BUDGET

Geometry

Uplink

Carrier & Environment

Transmitter

Receiver

Downlink

Carrier & Environment

Transmitter

Receiver

Results

About

GEOMETRY — UPLINK — DOWNLINK — RESULT

Import from JSatOrb

Satellite: CALSPHERE 2

Station: isae

Load

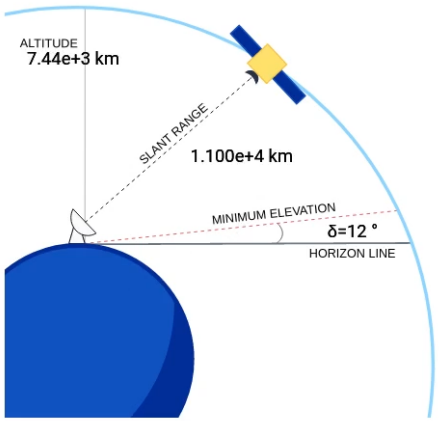
Geometry

Altitude: 7441.994990997203 km

Elevation Angle: 12 °

Slant Range: 11004 km

Documentation



δ is the minimum acceptable elevation angle. It is used for the calculation of the maximum slant range to the spacecraft. This range is then used to compute path losses. The slant range is calculated using the following formula :

$$S = R_e(\sqrt{[\frac{r}{R_e}]^2 - \cos^2\delta} - \sin\delta)$$

with:

S, the slant range in km
r, the distance of satellite from center of Earth in km ($r = R_e + h$)
R_e, the Earth's radius (in km)
δ, the minimum acceptable elevation angle

Uplink | Downlink

Transmitter	
Amplifier power	0.0
Circuit Loss	0.0
Antenna Gain	0.0
EIRP	0.0
Path	
Slant Range	0.0
Depointing Angle	0.0
FSL	0.0
Medium Losses	0.0
Total Path Loss	0.0
Receiver	
Isotropic power received	0.0
Pointing Losses	0.0
Antenna Gain	0.0
Circuit Loss	0.0
Noise Temperature	0.0
G/T Figure of Merit	0.0
Noise Power Density	0.0
C/N0 ratio	0.0
Bit Rate	0.0
Eb/N0 ratio	0.0

importing data

Demonstration

Luplink Diagram Simple Link Budget — Go back to JSatOrb — Default-mission — Compute

GEOMETRY — UPLINK — DOWNLINK — RESULT

Welcome

LINK BUDGET

Geometry

Uplink

Carrier & Environment

Transmitter

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Downlink

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Receiver

Results

About

Uplink Carrier

Frequency: 146 MHz

Bandwidth: 3 Hz

Bit Rate: 1200 bps

Eb/N0 Threshold: 23.2 dB

Implementation Loss: -1 dB

System Margin: 10 dB

Atmosphere

Depointing Loss: -0.9 dB

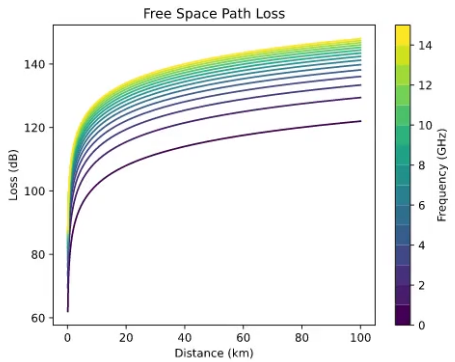
Cross Polarization: -3 dB

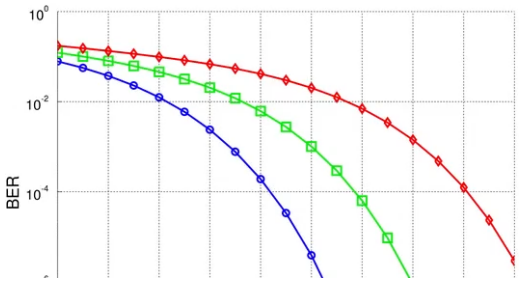
Atmosphere Gases:

Documentation

Carrier & Environment

Here we can define the carrier used for the uplink. The Free Space Path Loss (FSPL) and atmospheric losses depend on frequency but also polarization of the carrier. This graph shows the losses in dB due to propagation in free space as a function of distance between antennas and frequency of the carrier





Uplink | Downlink

Transmitter	
Amplifier power	0.0
Circuit Loss	0.0
Antenna Gain	0.0
EIRP	0.0
Path	
Slant Range	0.0
Depointing Angle	0.0
FSL	0.0
Medium Losses	0.0
Total Path Loss	0.0
Receiver	
Isotropic power received	0.0
Pointing Losses	0.0
Antenna Gain	0.0
Circuit Loss	0.0
Noise Temperature	0.0
G/T Figure of Merit	0.0
Noise Power Density	0.0
C/N0 ratio	0.0
Bit Rate	0.0
Eb/N0 ratio	0.0

Demonstration

Luplink Diagram Simple Link Budget — Go back to JSatOrb — Default-mission* — Compute

Export results as .md | Export results as .json

Welcome

LINK BUDGET

Geometry

Uplink

Carrier & Environment

Transmitter

Receiver

Downlink

Carrier & Environment

Transmitter

Receiver

Results

About

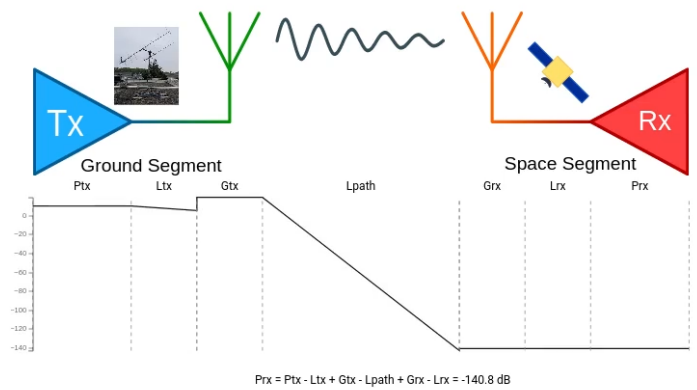
localhost:34355/luplink/results

Uplink

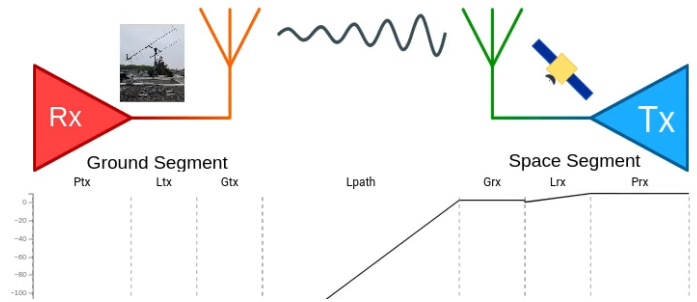
This link closes
Eb/N0 margin = 9.03 dB > 5 dB = System Margin

Transmitter	
Amplifier power	10.0 dBW
Circuit Loss	4.99 dB
Antenna Gain	14.0 dBi
EIRP	19.01 dBW
Depointing Angle	0.0 deg
Path	
Slant Range	11,004,000.0 m
FSL	156.57 dB
Medium Losses	5.4 dB
Total Path Loss	161.97 dB
Receiver	
Isotropic power received	-142.96 dB
Depointing Angle	0.0 deg
Antenna Gain	2.15 dBi
Circuit Loss	0.0 dB
Noise Temperature	299.93 K
G/T Figure of Merit	-22.62 dB/K

Synthesis Uplink



Synthesis Downlink



Downlink

This link closes with a low margin
Eb/N0 margin = 4.56 dB < 10 dB = System Margin

Transmitter	
Amplifier power	10.0 dBW
Circuit Loss	9.5 dB
Antenna Gain	2.15 dBi
EIRP	2.65 dBW
Depointing Angle	0.0 deg
Path	
Slant Range	11,004,000.0 m
FSL	156.57 dB
Medium Losses	5.4 dB
Total Path Loss	161.97 dB
Receiver	
Isotropic power received	-159.32 dB
Depointing Angle	0.0 deg
Antenna Gain	14.0 dBi
Circuit Loss	0.0 dB
Noise Temperature	297.18 K
G/T Figure of Merit	-10.73 dB/K

Outline

In conclusion

Lessons learned

- Use of web technologies for engineering problems
- Interfacing various tools together
- Interesting to see what could be done with other projects!
- Future Work : Collaboration with DOCKS?

Links

`https://gitlab.isae-supaero.fr/jsatorb-dev/luplink`
`https://www.npmjs.com/package/@luplink/ngx-luplink`

Thank you!

Institut Supérieur de l'Aéronautique et de l'Espace

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