Space Ops 101

An Introduction to Spacecraft Control

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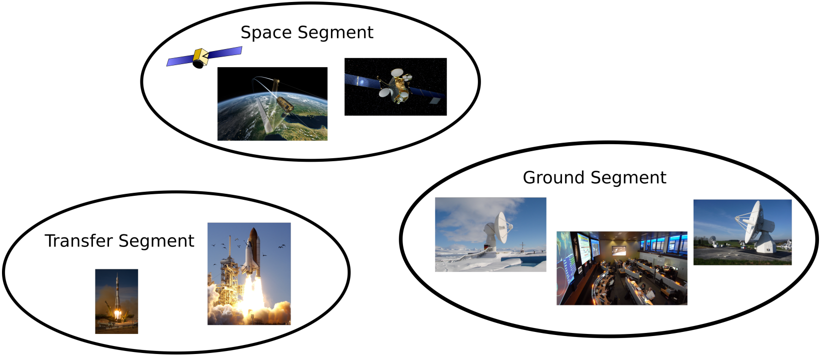
German Space Operations Center

27.12.2018

35c3

What we will not talk about ...

… but instead



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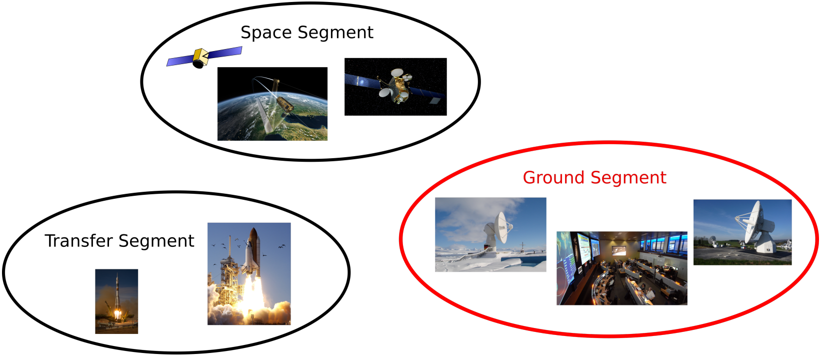

Outline

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- ...

Basics of Spaceflight

Why does a space craft not fall down?

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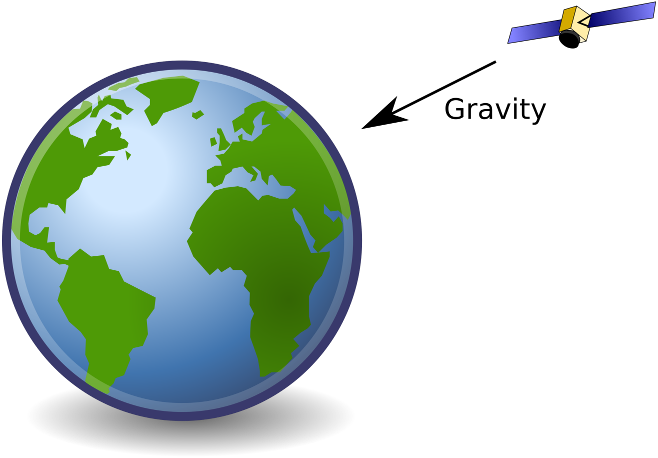

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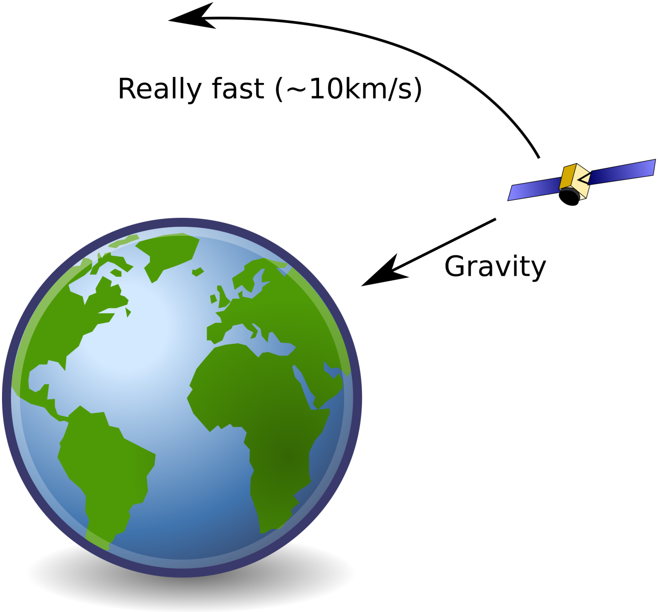
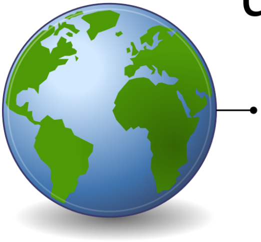


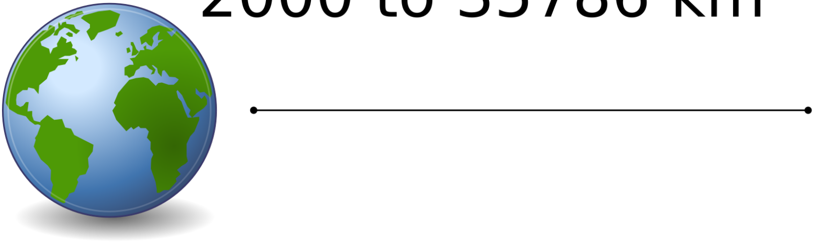
LEO, MEO and GEO

LEO, MEO and GEO

Low Earth Orbit
up to ~2000km



Medium Earth Orbit
2000 to 35786 km

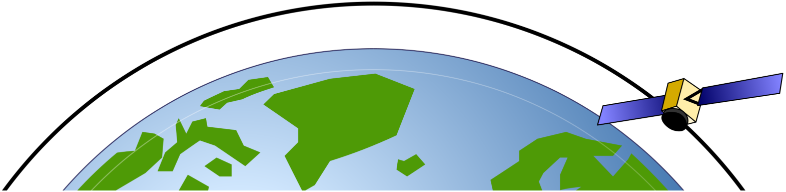


LEO, MEO and GEO

Geostationary Orbit
~35786km

Contacts and Passes

Contacts and Passes



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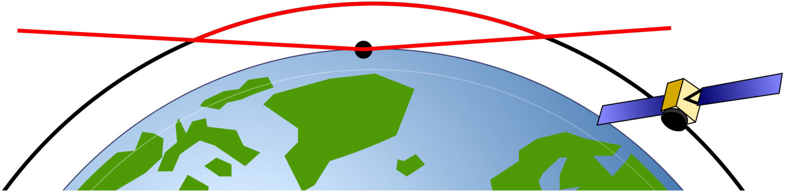
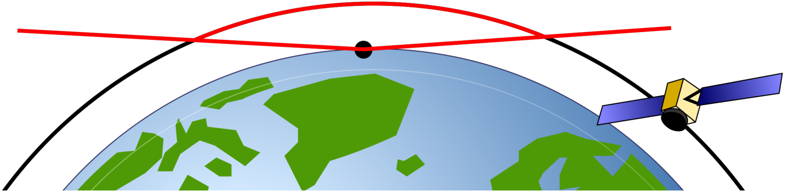


Contacts and Passes

600km altitude, 90min period, 5° elevation, ~11min contacts



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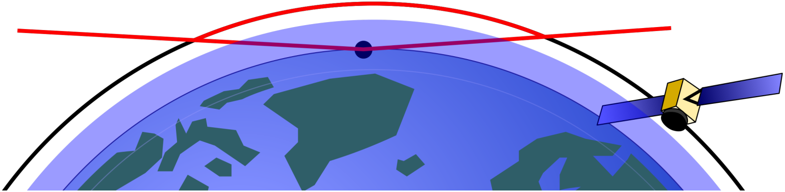

Ground Tracks

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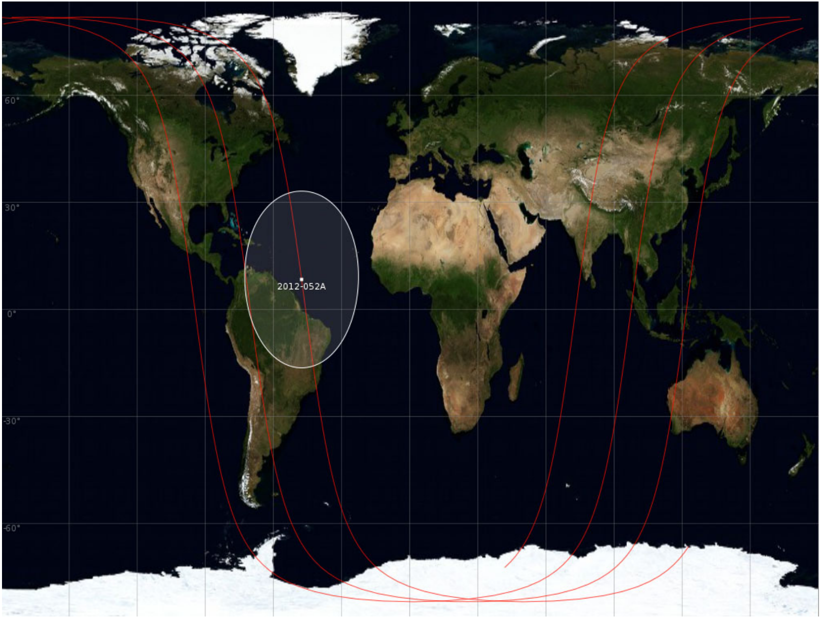

Frequency Range

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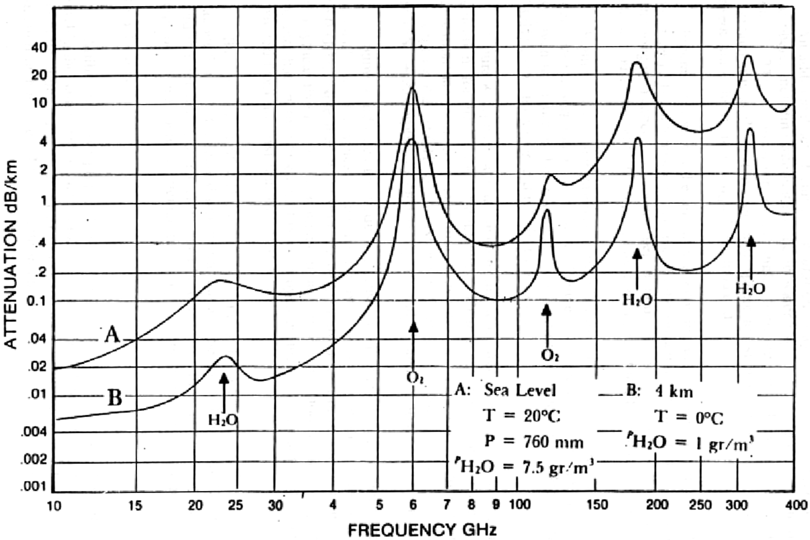

Figure 4: **Average Atmospheric Absorption of Millimeter Waves.**

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- Ka-Band: 26-40 GHz (?)

Up- and Downlink

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A satellite connection is used for

- downloading satellite telemetry ("house keeping data")

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A satellite connection is used for

- downloading satellite telemetry ("house keeping data")
- downloading payload data
- uploading commands
- uploading new software
- receiving and sending signals (as a relay)

Phases of Mission Operations

LEOP

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Launch and Early Orbit Phase

LEOP

Launch and **E**arly **O**rbit **P**hase

- Starts right after separation from transfer vehicle

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  - Unfolding of solar panels
  - Transfer Maneuvers to reach final orbit
  - First switch-on of star trackers, reaction wheels etc.

Commissioning or IOT

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In **O**rbit **T**esting

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  - Verification of payload
  - Test of routine operations

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- Main phase of operations

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- As much automatic operations as possible

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- As much automatic operations as possible
- Monitoring of the space craft
- Handling of contingencies
- Adaptations to changing mission objectives or changing properties of the space craft

End of Life

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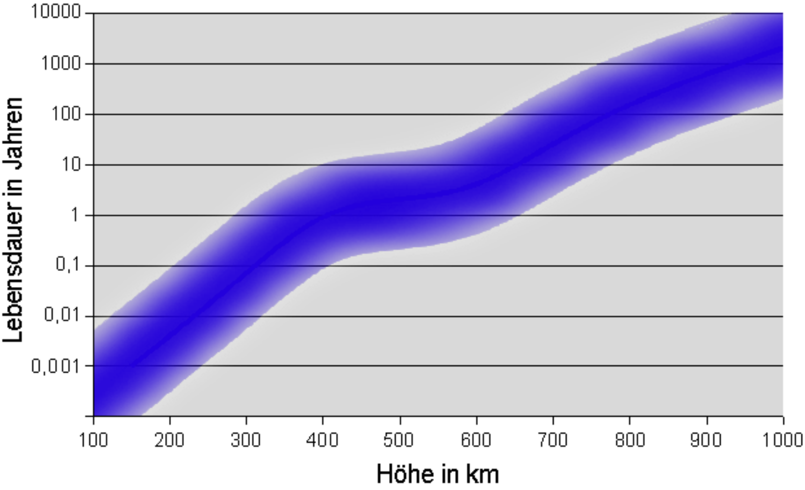

10000
1000
100
10
1
0,1
0,01
0,001
Lebensdauer in Jahren
100
200
300
400
500
600
700
800
900
1000
Höhe in km

Commanding and Monitoring

TCs and TTCs

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Telecommands (TCs) are used to command the S/C

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A TC

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Telecommands (TCs) are used to command the S/C

A TC

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- may set values on the S/C,
- may switch devices on the S/C or
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TCs can be time-tagged $\Longrightarrow$ TTC

Telemetry

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After processing this is saved in a space craft database

Examples for TTCs during a maneuver

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Time	Action
$t_0 - 00:60:00$	Check preconditions
$t_0 - 00:59:52$	Heat thrusters
$t_0 - 00:11:00$	Switch on additional telemetry
$t_0 - 00:09:40$	Turn off safeguards
$t_0 - 00:06:40$	Rotating space craft
t_0	Burn starts
$t_0 + 1.1 \cdot \text{burn time}$	Additional safeguard STOP command
$t_0 + 00:00:01$	Rotate back
$t_0 + 00:13:00$	Turn off heaters
$t_0 + 00:14:54$	Turn back to old mode

Flight Procedures

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A flight procedure (FOP) is a sequence of

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- TCs and

Flight Procedures

A flight procedure (FOP) is a sequence of

- TM-checks,
- TCs and
- some simple logics such as loops or conditions

Does a specific task on the S/C in a consistent and safe manner

Preparation and Validation of FOPs is one of the main works in preparation phase for the mission

Ground Procedures

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Needs to be simple, concise and doable at 3am by anybody in the OPS team

Examples:

- How to restart some software
- How to command a change of the mode of a S/C via a FOP

Subsystems

Control Room

Control Room

FDS and AOCS

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Flight Dynamics (FDS) does *orbit propagation*,

FDS and AOCS

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FDS and AOCS

Flight Dynamics (FDS) does *orbit propagation*,*ground station visibilities*and *maneuver calculations*

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Attitude and Orbital Control System (AOCS) is responsible for S/C operations regarding *attitude*,*tumbling*,*maneuver execution*and *positioning*

Target-Pointing-Mode

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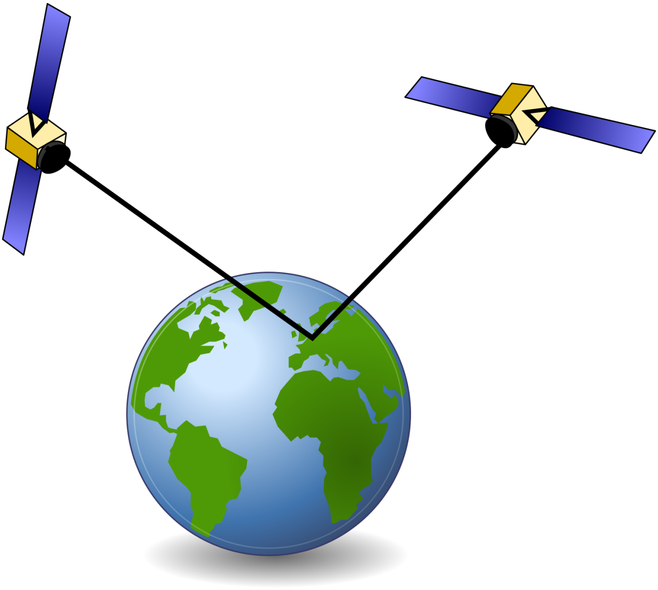
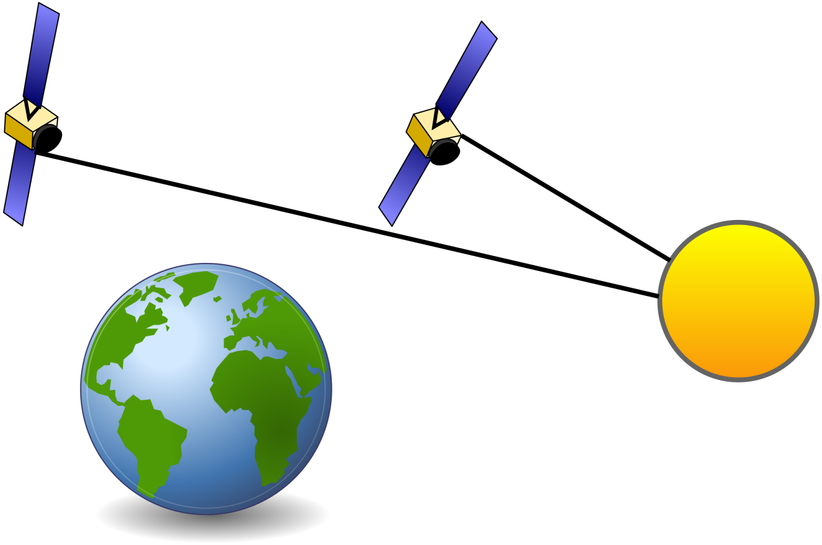


Sun-Pointing-Mode



Data and TM/TC

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- Acquisition and maintenance of signal/TM-flow,

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- Acquisition and maintenance of signal/TM-flow,
- Ranging,
- Data processing

SCOS


Command
Flight
Data
ACS
KANOPUS-V-IK CLUSTER MISSION 2017
Universität Stutt

PTR

PTR

Power and Thermal (PTR) monitor

- battery state and

PTR

Power and Thermal (PTR) monitor

- battery state and
- temperatures on the S/C

Temperatures can easily range from $-60\,\text{deg}\,C$ to $+100\,\text{deg}\,C$

Long term monitoring very important

MiPL

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Mission Planning (MiPL) takes care of

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- executing automated FOPs in routine operations and
- detailed planning during the LEOP

Sequence of Events

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TODO add picture sample SoE

Contingencies

Flight and Engineering Model

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There exists an engineering model of the S/C and simulators for

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- connection tests and
- reproducing errors on the flight model

Procedure in Case of Contingency

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Stay calm!

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Verify your input data

Procedure in Case of Contingency

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Call people responsible for that sub system

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Analyze possible failure causes ("Next pass ...")

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Test solution

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Test solution

Execute solution

Example Contingency: TV-SAT 1

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German-French TV satellite from 1987

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First acquisition successful, but solar-array deployment switch said that solar panels were only partially deployed

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$\Longrightarrow$ We have a problem!

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Offline analysis by the satellite manufacturer showed more than 50 possible failure cases $\Longrightarrow$ We need tests!

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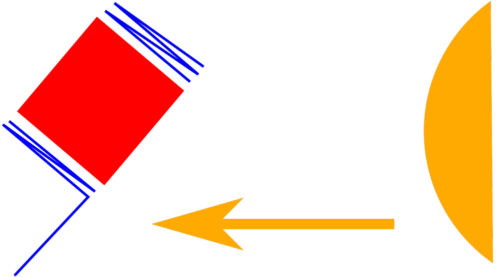

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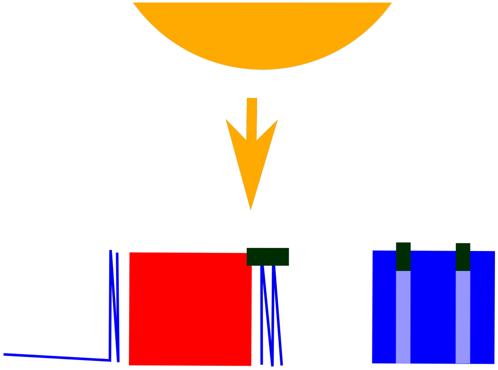

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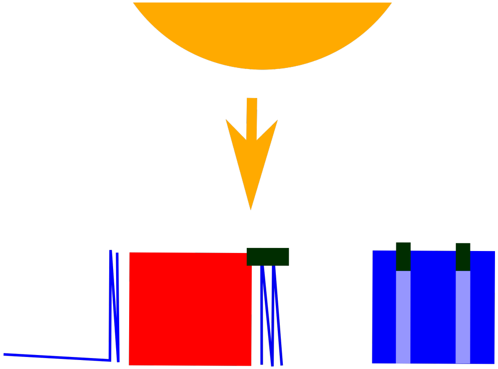
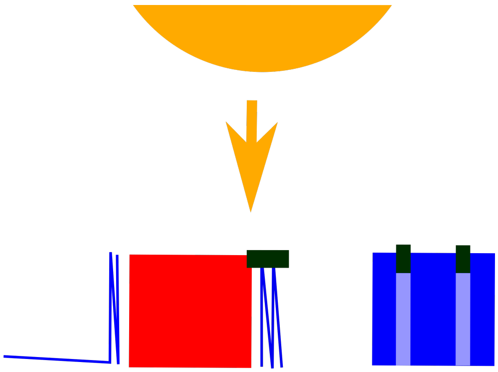


More tests (Rotating S/C in another axis and measureing flux, shaking of S/C to find resonance frequencies) all showed:

Example Contingency: TV-SAT 1



More tests (Rotating S/C in another axis and measureing flux, shaking of S/C to find resonance frequencies) all showed: The solar panels were indeed not deployed.

Example Contingency: TV-SAT 1

Recovery attempts:

Example Contingency: TV-SAT 1

Recovery attempts:

- Fast rotation (1g centrifugal force) to loosen stirrups

Example Contingency: TV-SAT 1

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- Performing pulsed boosts to excite resonance frequencies

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Recovery attempts:

- Fast rotation (1g centrifugal force) to loosen stirrups
- Performing pulsed boosts to excite resonance frequencies
- Heating and cooling panel and stirrups

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Recovery attempts:

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- Antenna deployment causes a shock to the S/C

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All in all: no success :-(

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- Fast rotation (1g centrifugal force) to loosen stirrups
- Performing pulsed boosts to excite resonance frequencies
- Heating and cooling panel and stirrups
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All in all: no success :-(

But usually everything works fine!

Questions?

Thank you and enjoy the rest of the congress!