Status of Active Debris Removal (ADR) developments at the Swiss Space Center

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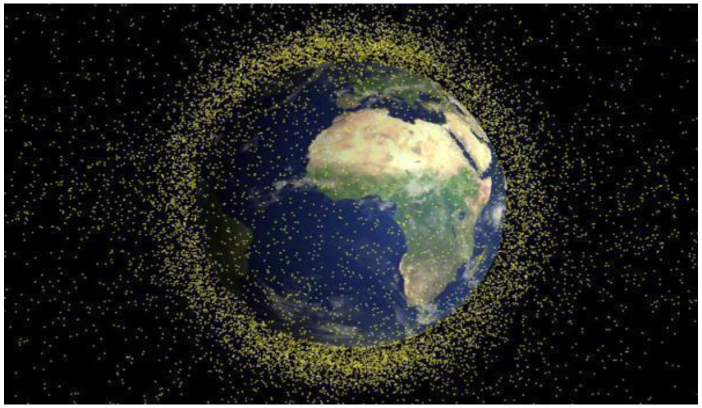

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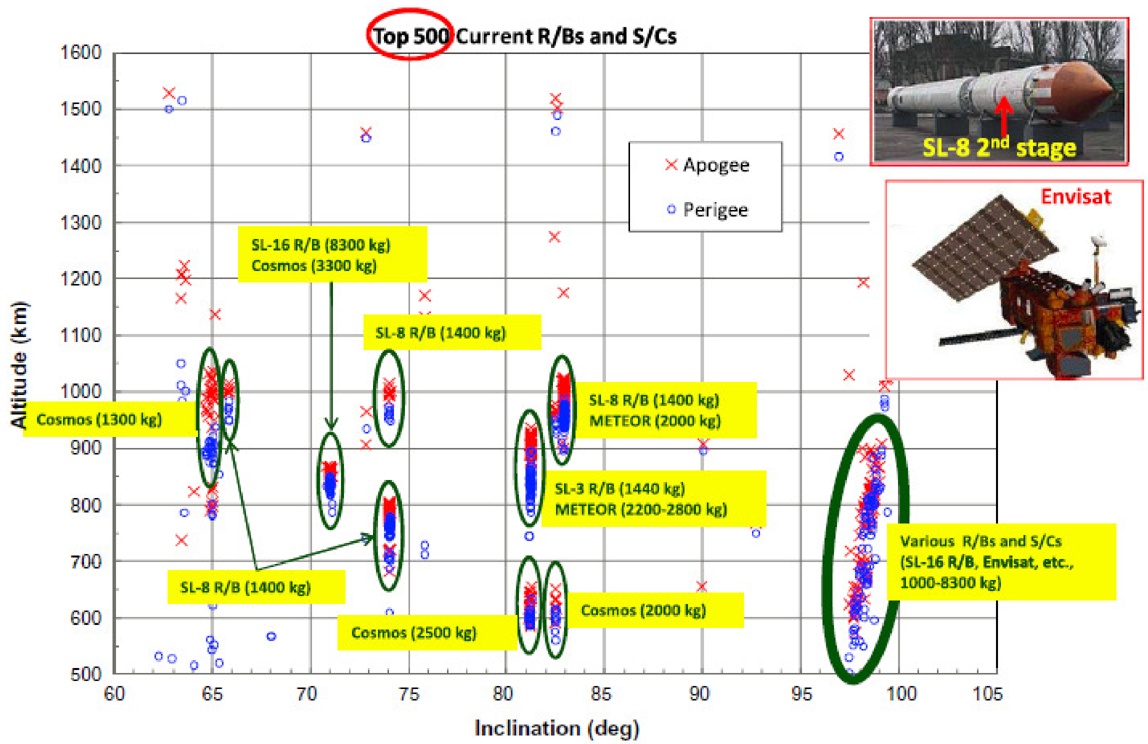
ADR mission architecture studies

- **Questions:**
  - What is the best architecture (= cheapest?) to remove 5-10 large debris per year ?
  - What is the best way to get organised internationally? (not yet answered)

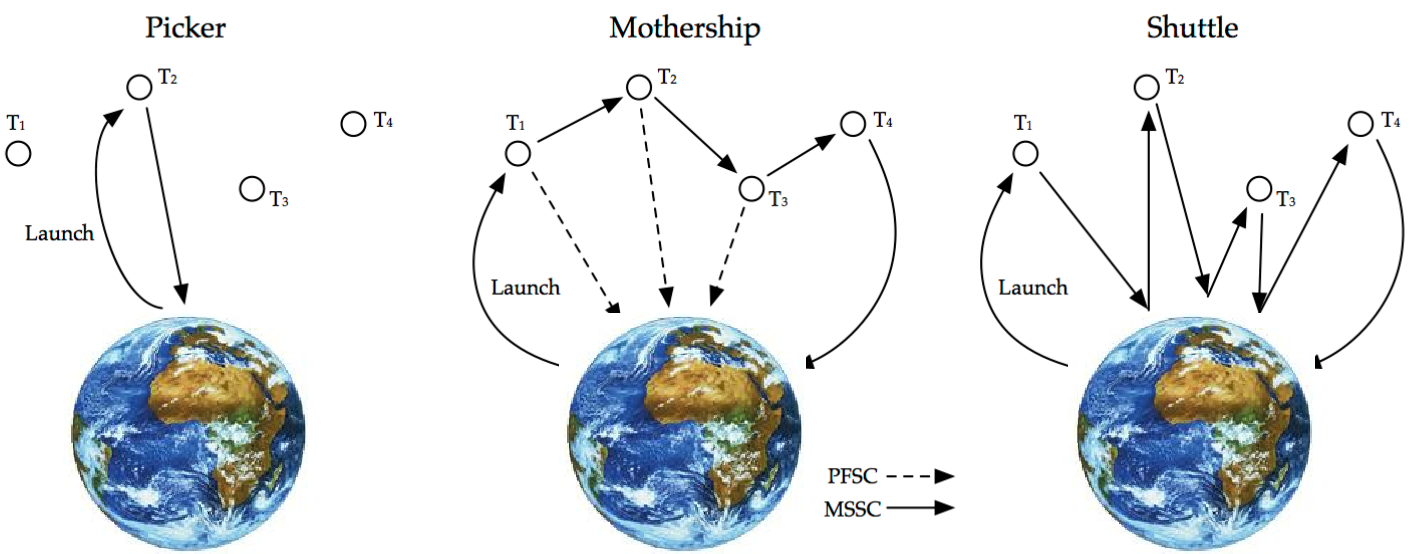
- **Considering population of "500 most wanted debris" [R1]:**
  - Mostly large rocket bodies
  - 1000 – 8000 kg
  - Mostly 71º, 81º, 83º and SSO inclinations



[R1] "An active debris removal parametric study for LEO environment remediation", J.-C. Liou, NASA Johnson Space Center, Advances in Space Research 47 (2011) 1865–1876

ADR mission architecture studies

- **In collaboration with MIT (USA, Prof. O. De Weck), we have developed a mission architecture tool that:**
  - Considers various mission architectures



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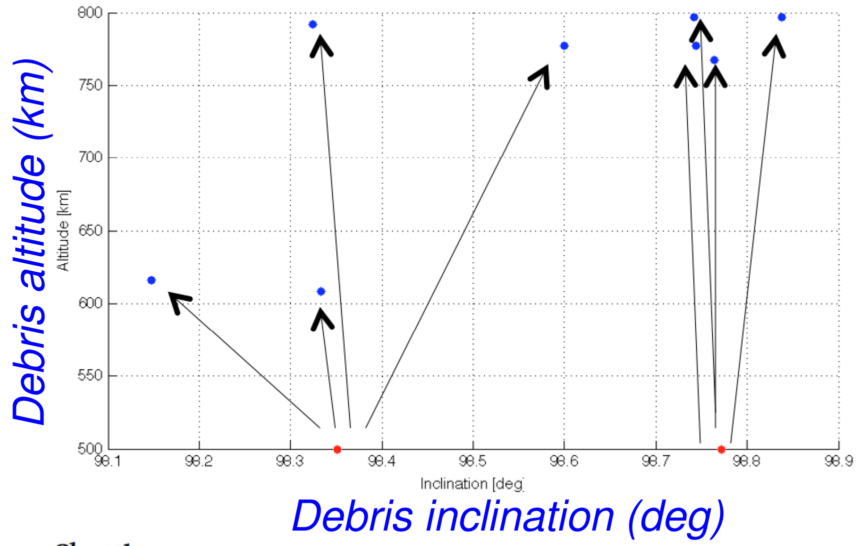

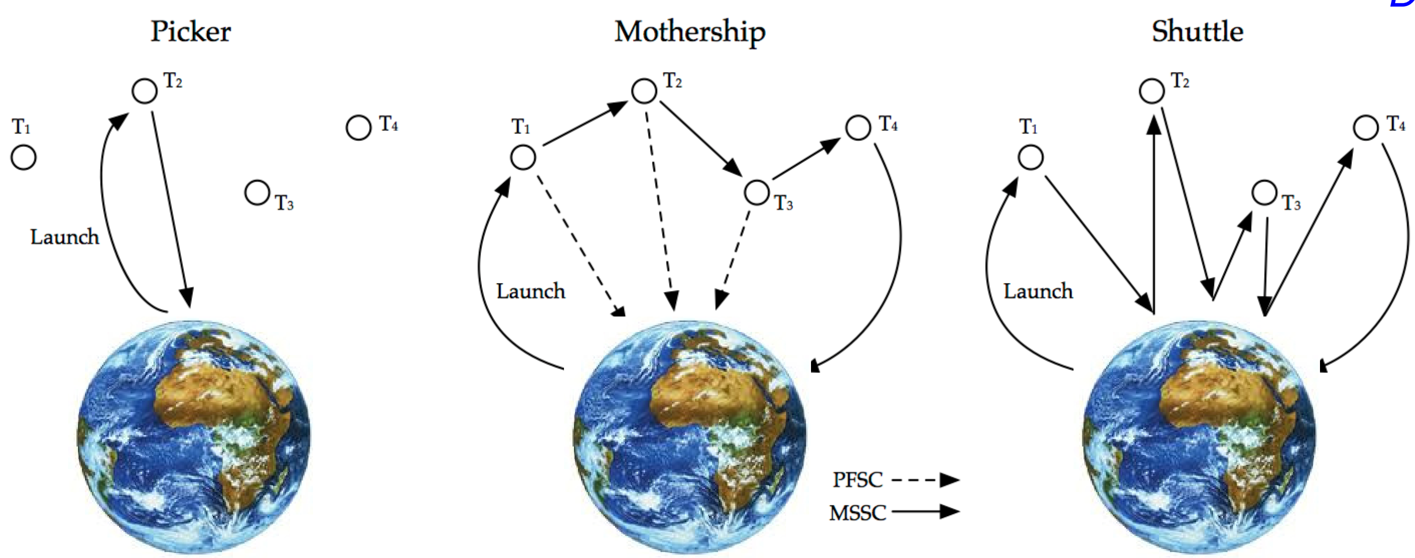

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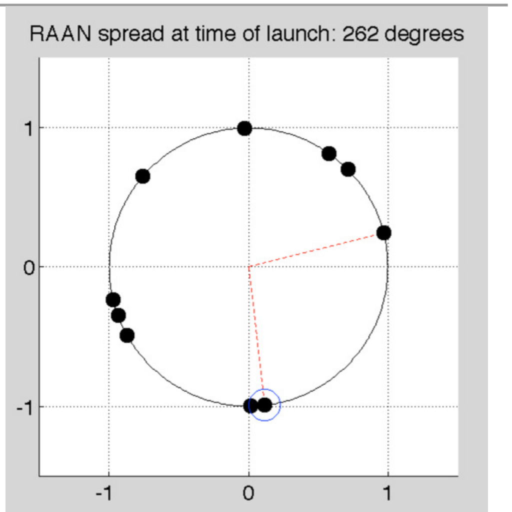
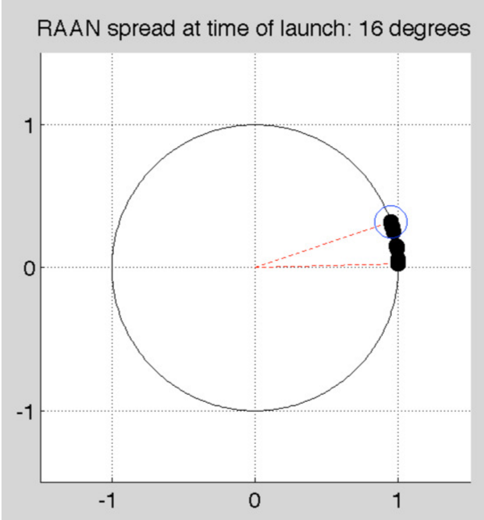


Spread in RAAN at launch minimized



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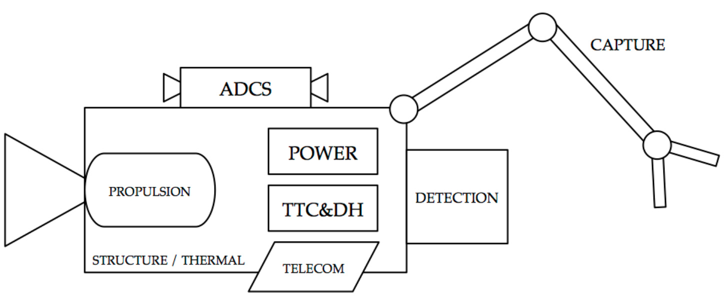
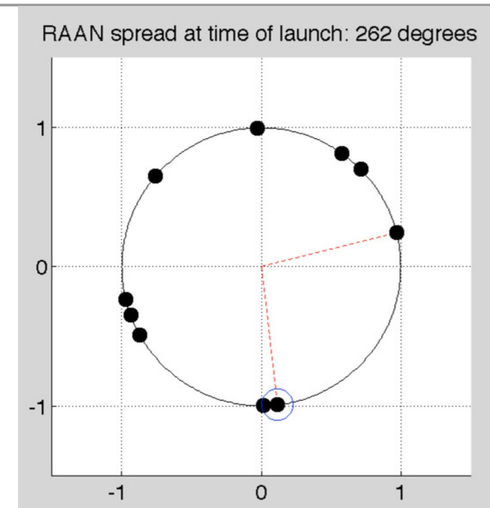


Mass
Power
Cost



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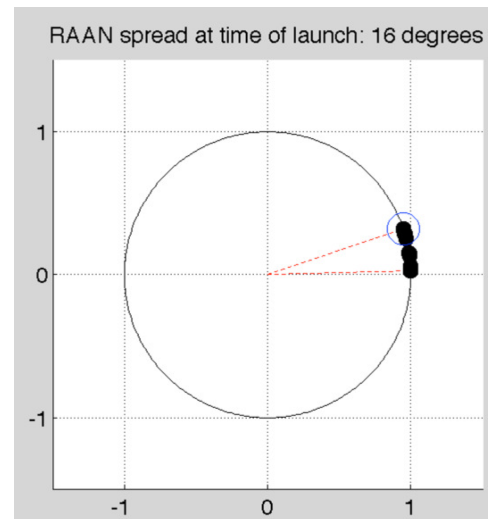

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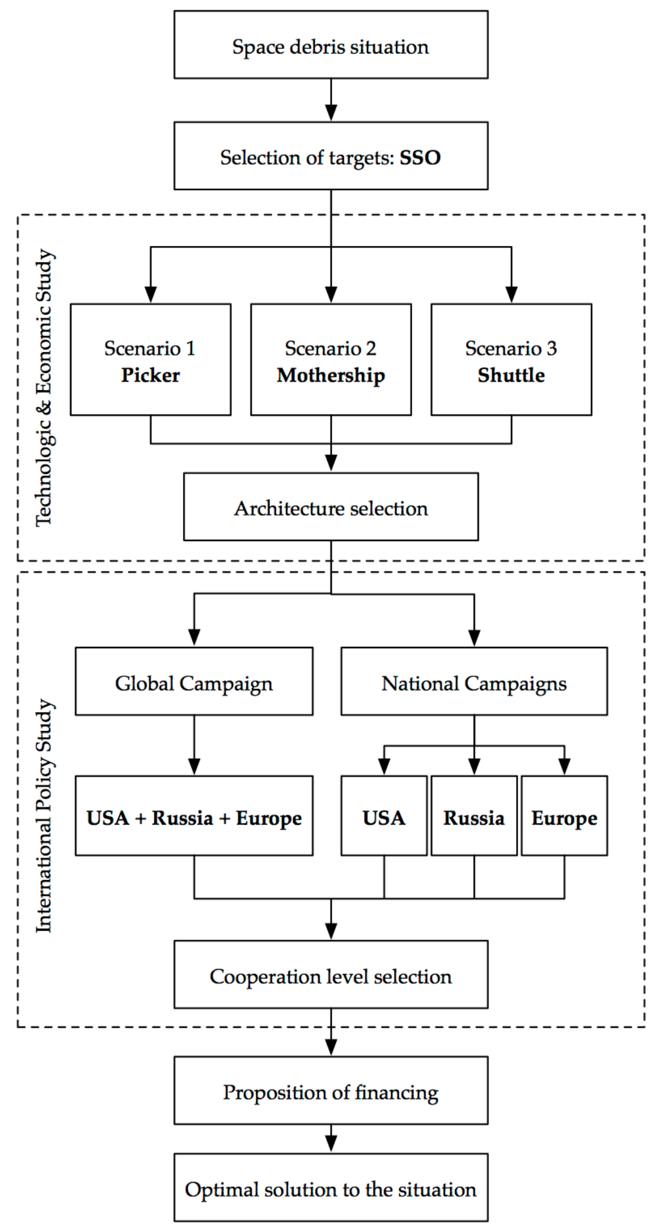
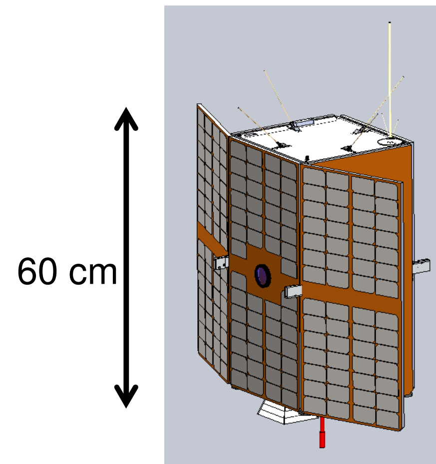
  - Provides a parametric mission and debris removal campaign cost

First results to be published during 6th European Conference on Space Debris, 22-25 April 2013, Darmstadt, Germany

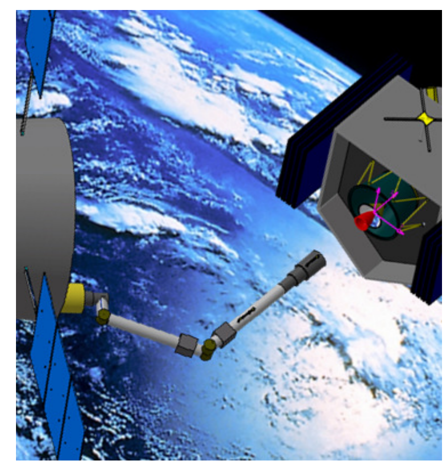


ADR demonstration opportunity

- **Participated in EC FP7 Call SPA.2013.2.3-02: "Security of space assets from in-orbit collisions"**
- **This call asks for a demonstration mission, which purpose is to perform an in-orbit removal of debris in a low-cost manner**
- **Consortium coordinator: GMV (Spain)**
  - Partners: Univ. Bologna, ALMASpace, Thales Alenia Space, EPFL, TSD, Univ. Roma La Sapienza, Poli Milano, ONERA, D-Orbit, DTM
- **Will test and validate:**
  - Guidance, Navigation & Control, before and after capture
  - Vision based approach system
  - Multi-capture demos, inc. Robotic and/or Net capture
  - Mission operations concept, autonomy level



EuroCleanSat preliminary configuration (courtesy ALMASpace)



Conceptual robotic approach for illustration purposes (courtesy TASI)

Optical detection of debris

- **In collaboration with Uni-Bern Astronomical Institute (Prof. T. Schildkecht), preparing an optical characterisation of SwissCube CubeSat**

- **AIUB has a long experience in the field of debris observation (mainly in high-altitude orbits, GEO/GTO/MEO)**
  - Based on optical observations with the telescopes at the Zimmerwald observatory and in Teneriffe, AIUB developed high precision propagators to predict the position of debris objects, including high area-to-mass ratio objects
  - Has a permanently updated debris catalogue and algorithms to identify and extract debris objects from telescope images
  - AIUB is also trying to identify shape, size and rotation states using light curve analysis.

Optical detection of debris

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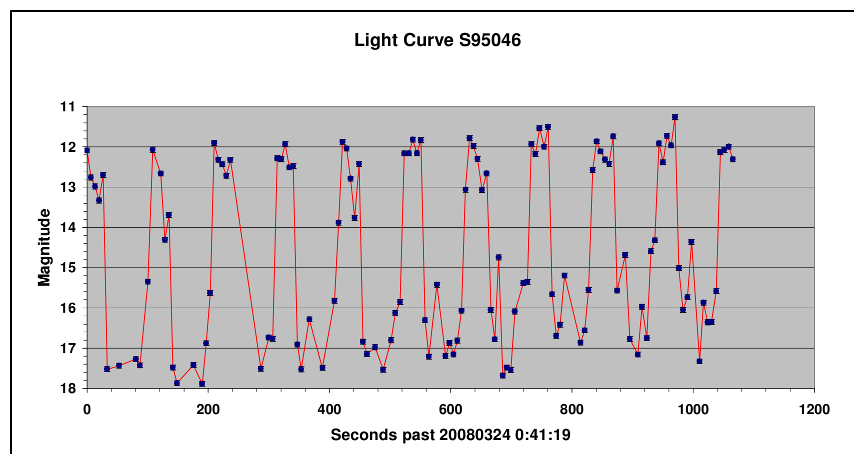
- **Future developments:**
  - More advanced propagators, identification of debris shapes, rotation rates and spin axis orientation using light curve analysis and direct imaging
  - Improved and automated observation technologies
  - Debris detection and tracking using the Zimmerwald Satellite Laser Ranging (SLR) station

- **Interests of AIUB:**
  - Verify AIUB's orbital determination/observations with on board-measurements
  - Verify light curve spectra
  - Verify on-board observation/tracking techniques (algorithms)
  - Have onboard telescope images on ground for comparison.



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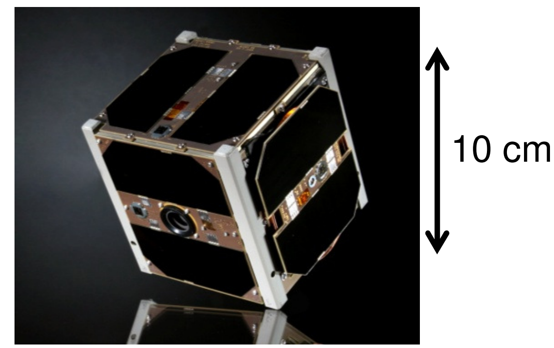
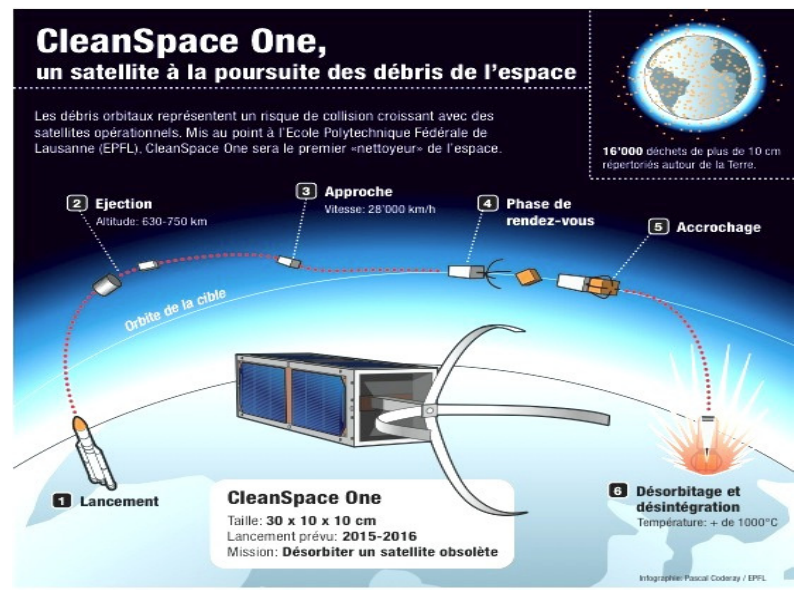
CleanSpace One Project

- **After the launch of SwissCube CubeSat (Sept. 2009), started ADR technology program called "*Clean-mE*"**

- **Research and development most efficient when targeted to a concrete application**
  => Start of *CleanSpace One* project

- **The objectives of the CleanSpace One project are to:**
  - Increase awareness, responsibility in regard to orbital debris and educate aerospace students
  - Demonstrate technologies related to Orbital Debris Removal
  - De-orbit SwissCube.



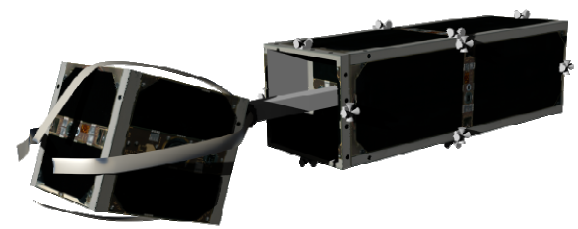


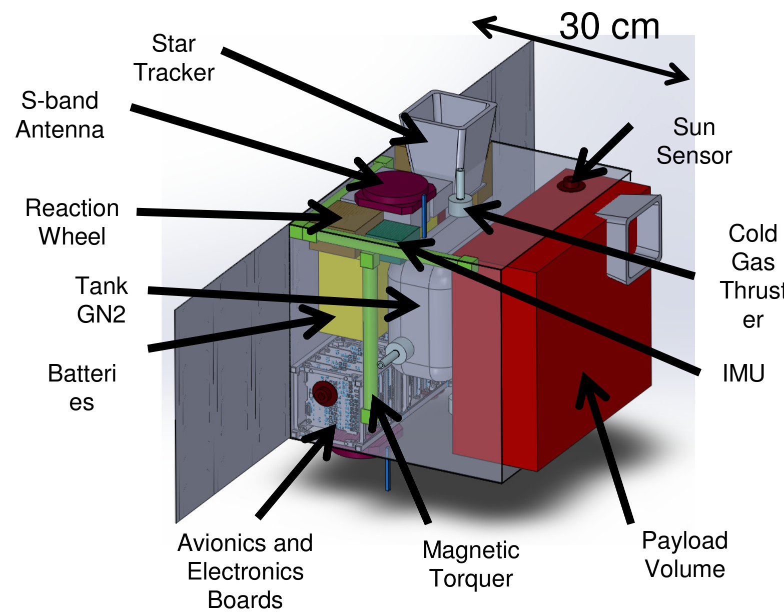
CleanSpace One NanoSat

- **CleanSpace One nanosat:**
  - Based on a CubeSat platform as preliminary assumption
  - Preliminary (Phase 0) design done using CDF
  - Launch ~ 2017

- **Critical technologies provided by partner institutions (open to international cooperation). Satellite platform designed by students.**

- **Operations performed by students in partnership with professional institutions**



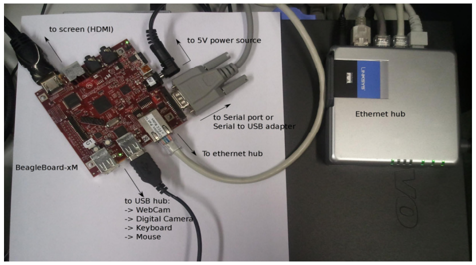


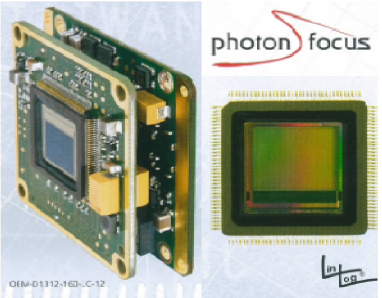
CleanSpace One conceptual design

Vision based systems – current work

- **With EPFL Prof. J-P. Thiran's laboratory, research developments for one 2-D camera and optical flow**
  - Motion reconstruction algorithms
  - Algorithms developed, first iteration
  - Current process: creation of representative images, characterisation of algorithm performances

- **Hardware implementation**
  - Cameras: have discussions with Space-X and with PhotonFocus
  - Evaluation of various CubeSat based computers

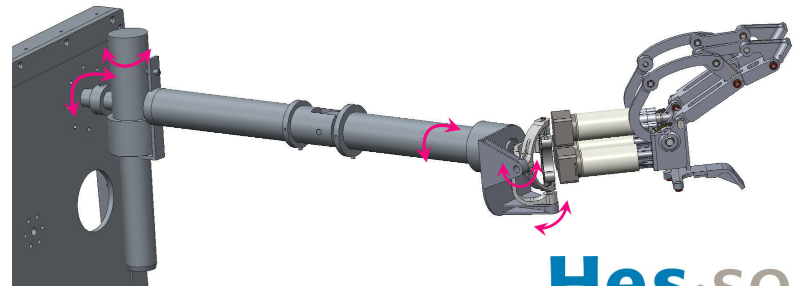




C. Paccolat, Master thesis EPFL July 2012

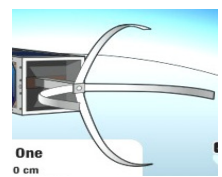
Capture mechanisms – current work

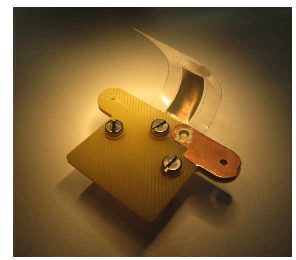
- **Three designs in parallel:**

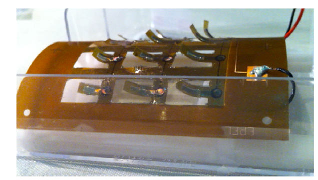


1. Underactuated mechanisms

- Work under/in cooperation with Prof. Lauria, HES-Geneva

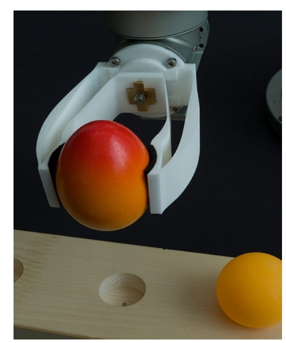






2. Dielectric polymer actuators

- Work under/in cooperation with Prof. H. Shea



3. Compliant mechanisms

- Work in cooperation with F. Campanile, EMPA

Conclusions

- **The Swiss Space Center is pursuing mission architecture studies and development of technologies needed for Orbital Debris Removal**

- **Participation in mission oriented proposals**
  - CleanSpace One project in fund raising phase, student team started in September 2012
  - EC FP7 ADR
  - Nanosat demonstrators have three major advantages:
    - Tests and demonstrates key elements for orbital debris removal, focuses the development on something real
    - Relatively cheap demonstration mission, proposes low-cost mission options
    - Continues education in a very motivating field

- **Our goal is to help community, fill in technology gaps, and propose low-cost solutions that integrates within international developments**