Activities in Active Debris Removal (ADR)

CleanSpace One Project

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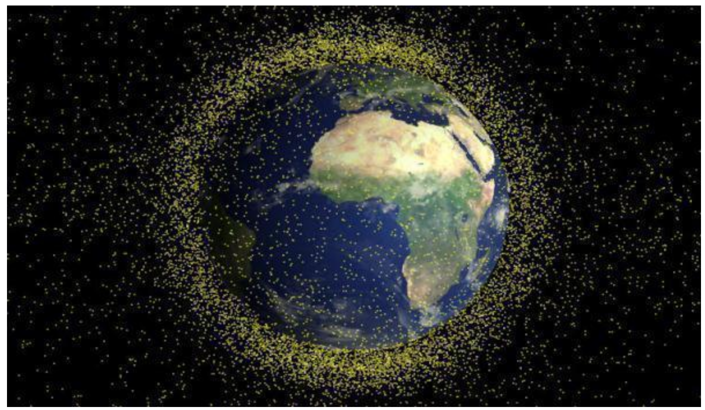
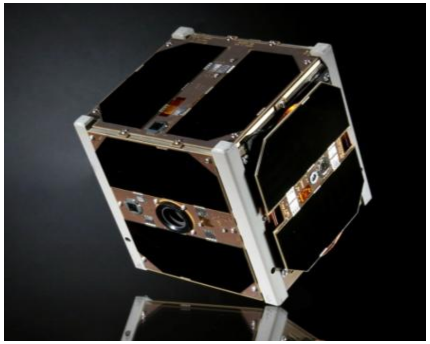


Context

- **Swiss Space Center launched SwissCube, the first Swiss student satellite, in September 2009**
  - **CubeSat family (10 x 10 x 10 cm3, 1 kg)**
  - **SwissCube is on 720-km SSO orbit, still operational**



- **After the launch, started research to develop technologies for Orbital Debris Removal of Non-Cooperative Debris (under a program called “*Clean-mE* ”)**
  - **Low level funding**

- **CONCLUSION: research and development most efficient when targeted to a concrete application**

  => Start of *CleanSpace One* project

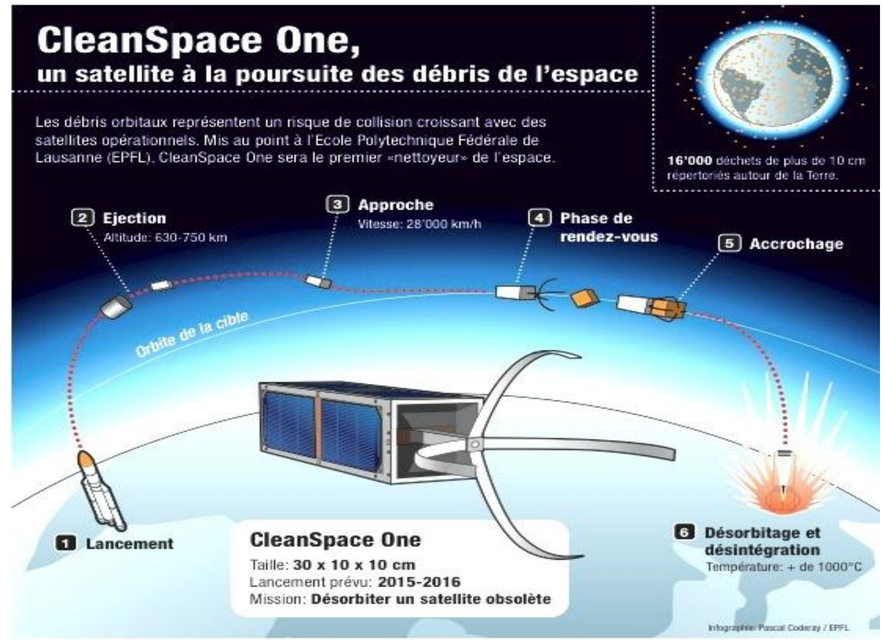
Project Objectives

- **The objectives of the *CleanSpace One* project are to:**

  1. **Increase awareness, responsibility in regard to orbital debris and educate young people;**

  2. **Demonstrate technologies related to Orbital Debris Removal;**

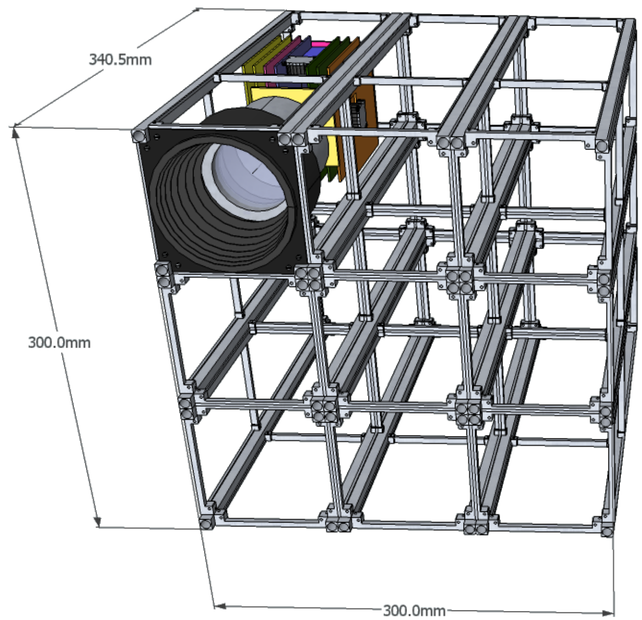
  3. **De-orbit a known and politically acceptable debris.**



CleanSpace One NanoSat

- *CleanSpace One* NanoSat
  - Remove 1 debris (> 10 cm, < 1m)
  - Based on a CubeSat 3U-6U platform as preliminary assumption
  - Preliminary (Phase 0) design done using CDF
  - VEGA or PSLV, launch ~ 2016-17

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



- Operations performed by students in partnership with larger and professional institutions

Technical Challenges for *CleanSpace One*

- ***In orbit maneuvering and Rendezvous***
  - Development of highly efficient propulsion system and attitude control system for a nano-satellite to minimize amount of fuel that need to be carried. Key factor is how close can a launch vehicle deliver our flight system to the target.

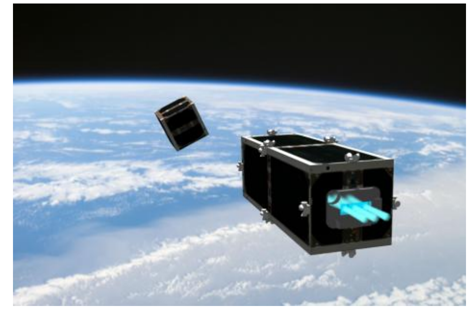
- ***Target identification & tracking***
  - Employ passive (Vision Based System) instruments to identify object and characterize its state (position and rotations)
  - Perform in phase manoeuvring, with high level of autonomy

- ***Grappling, safe, versatile, adaptative and reliable***

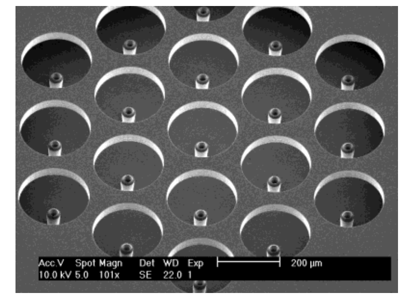
- ***Controlled de-orbiting maneuver***
  - *May not be any issue is CleanSpace One is small enough*

swiss space center

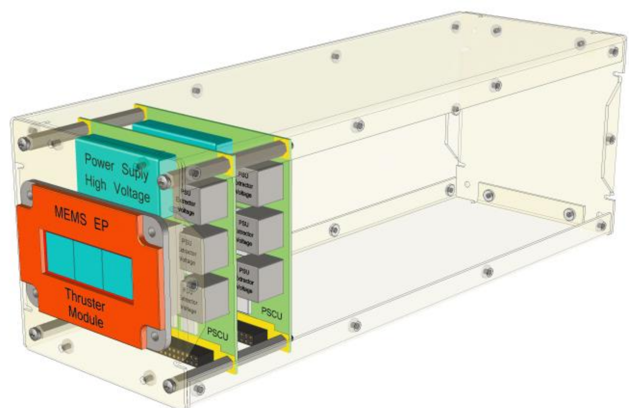
Micro-propulsion system

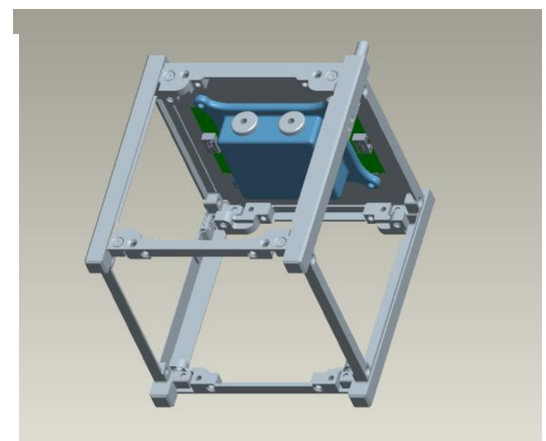


- **Propulsion needs to remove SwissCube:**
  - **Orbit altitude matching ~ 120 m/s (from 500 km)**
  - **RAAN changes ~ 50 m/s**
  - **Inclination change ~ 100 m/s**
  - **De-orbit DV ~ 230 m/s (to get to 3-yr deorbiting orbit)**



- **Current work: MicroThrust (www.microthrust.eu)**
  - **FP7 activity with TNO, NanoSpace, QMUL, SystematIC and EPFL**
  - **Development of a breadboard in 2012, tests in 2013**
  - **Expected performances > 500 m/s at Isp 3000 s**





CleanSpace One SWISS SPACE CENTER

Micro Thrust

SEVENTH FRAMEWORK PROGRAMME

Vision based systems – current work

- **Evaluating motion estimation algorithms**

Motion estimation techniques evaluation

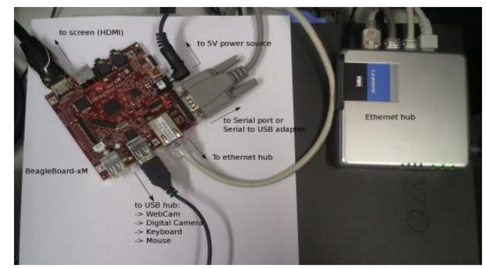
Close Range Operations

Fonction

Motion & Structure estimation
- 3D imaging technologies
- 2D Cameras

Algorithmics / Evaluation

3D imaging technologies: Aghili & Parsa (2008), CSA	3D imaging technologies: Hillenbrand & Lampariello (2005), DLR	2D Cameras: Angles-Only	2D Cameras: Optical Flow	2D Cameras: Structure From Motion	2D Cameras: Stereo-Camera
• Assumes known orientation of the target • Models dynamics of target and predicts pose and orientation accurately up to 20 s. ahead • Reasonable performances with measurements at 2Hz: <10% on position, <15° on orientation • Requires consequent processing capabilities	• Assumes depth and space correspondence between sensed points • Models motion and dynamics • Reasonably good prediction accuracy (100 s) : 52% of measurements below 10 cm position / 20° orientation error • Extensions with stabilisation of target have been developed • High processing power required for decent performances (40Hz @~4500MIPS, with 100 points)	• Provides only position and distance of the target • Possible method for MRO (navigation to the target) • Lowest processing requirements	• Long heritage • Motion estimation only • Low power requirements • Implementation available • Minimal development required • Can reconstruct depth	• Similar to SLAM (Simultaneous Localisation And Mapping) • Motion estimation only • Notable heritage from DARPA challenge • High computing power required • Some developments required	• Noise & error propagation issues • Calibration required • Requires consequent processing capabilities (optimisation methods)



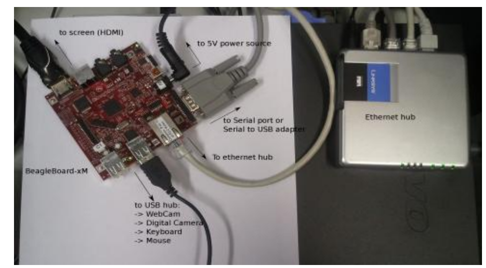
C. Paccolat, Master thesis
EPFL July 2012

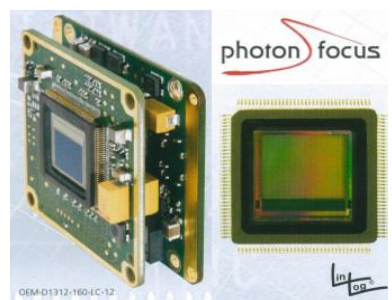
Vision based systems – current work

- **Evaluating motion estimation algorithms**

- **With EPFL Prof. J-P. Thiran's laboratory, research developments for one 2-D camera and optical flow**
  - **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**



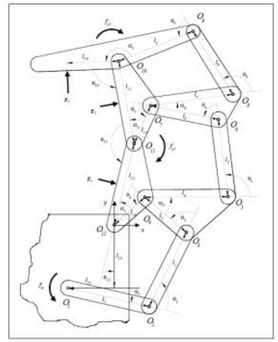


C. Paccolat, Master thesis EPFL July 2012

Capture mechanisms – current work

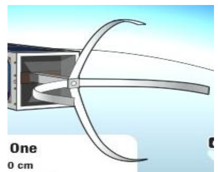
- **Three designs in parallel:**

1. **Underactuated mechanisms**
   - Work under/in cooperation with Prof. Lauria, HES-Geneva



University of Laval concept

2. **Dielectric polymer actuators**
   - Work under/in cooperation with Prof. H. Shea



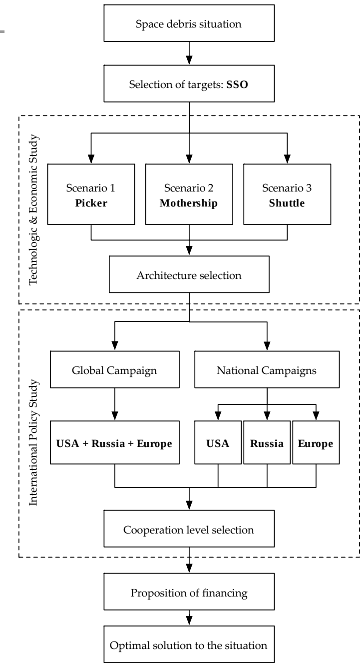
3. **Compliant mechanisms**
   - Work in cooperation with F. Campanile, EMPA

Other related activities

- **Mission architecture studies**
  - **High level mission architecture tool elaborated within a joint EPFL / MIT master thesis**
  - **Purpose is to evaluate technology options and mission cost versus mission architecture**

- **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**
  - **SSC proposes (low-cost) platform design**

- **Approach and capture test**
  - **Student project: 5 Master, 6 semester projects**
  - **Prototype demonstration of rendezvous maneuvers**
  - **Test in a swimming pool**



Summary *CleanSpace One*

- **The Swiss Space Center has started the development of critical and innovative technologies needed for Orbital Debris Removal**

- **The Swiss Space Center provides an efficient frame for supervising research and tailoring it to space applicable demonstrators**

- **Swiss Space Center's plans are meant to be in line with European space agencies and industries**

- **CleanSpace One project in fund raising phase, student team started in September 2012**