WEAR
WEarable **A**ugmented **R**eality

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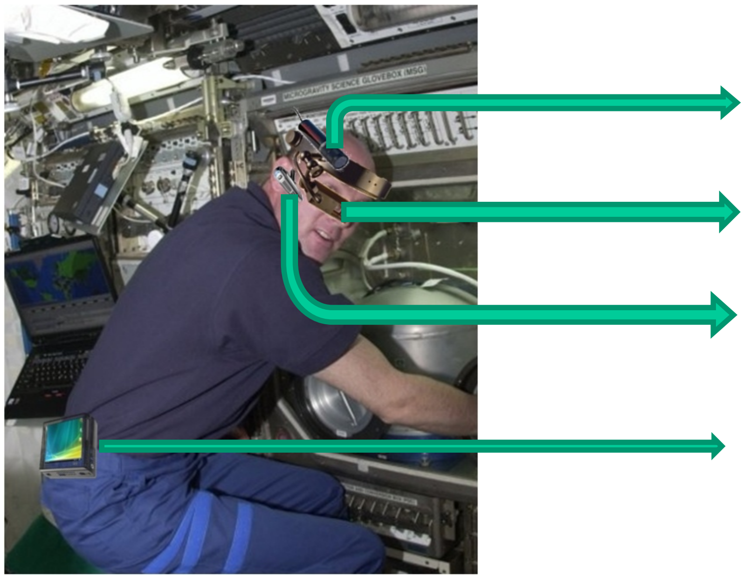
Hardware Components



USB Camera

USB Head mounted display

headset (mic+headphone)

Payload Laptop A31P

WEAR comprises an OTS (off-the-shelf) see-through Head Mounted Display (HMD) that has an OTS camera integrated on it and a headset for speech recognition and synthesis. All this is connected using VGA and USB to an onboard IBM A31p laptop. This laptop is one of the 5 ESA dedicated payload laptops within Columbus. The WEAR application software and the IMS database is delivered on a replaceable A31P laptop hard disk.

Application Domains Specificities

Space

- Specific working conditions:
  - inside a space vehicle
  - orbiting in LEO
  - microgravity
  - no GPS signal
  - weak, noisy and varying magnetic field
  - known environment (CAD models)
  - Operation range: 0,8m to 5m
- Sensor technology:
  - Computer Vision Based Tracking + Inertial Measurement Unit (IMU)
  - Barcode Scanning

Architecture, Civil Engineering and Urban Planning Applications

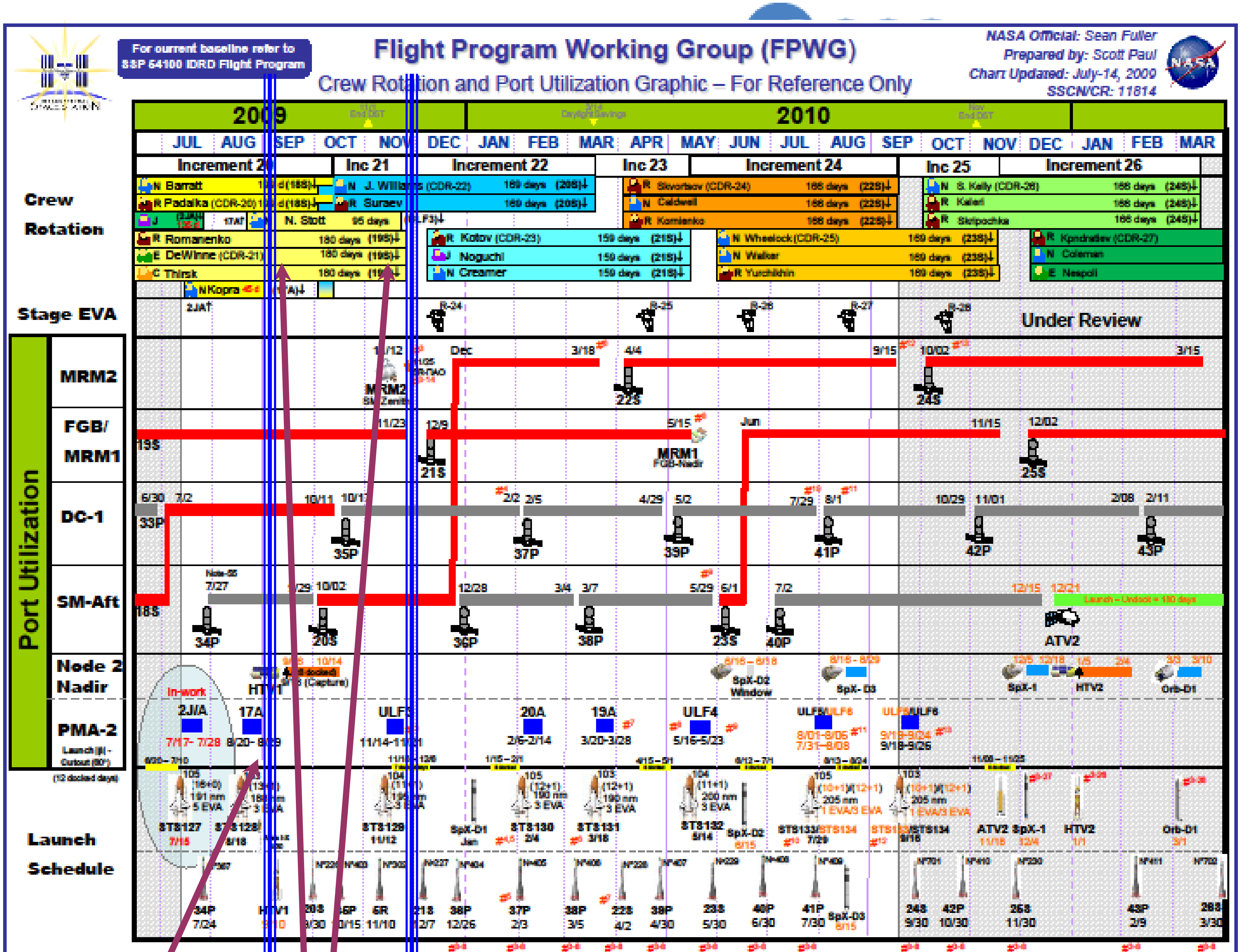
- Specific working conditions:
  - on ground
  - outdoor
  - Availability of EGNOS Satellite Based Augmentation System
  - Digital Elevation Models
  - Operation range: 10m to 2.000m
- Sensor technology:
  - EGNOS GPS receiver + Inertial Measurement Unit (IMU)

WEAR SDTO Schedule

• RIP Informational Brief	8 October 2008
• CR Release	14 October 2008
• TCM (Technical Coordination Mtg)	12 November 2008
• MIOCB Approval	20 November 2008
• Environmental Tests	January 2009
• WEAR QAR	5/6 March 2009
• Training	17th March 2009
• final satefy review	17th March 2009
• Requested manifest	17A (August 25, 2009)
• Delivery to KSC and Bench Review	April 24, 2009
• Requested execution	Increment 20/21
• WEAR sessions	19 Sept. & 28 Nov 2009

- Safety DP I/II to ESA & IOT IEHA
- Safety DP I/II to NASA
- Hardware certification
- Safety DP III to ESA & IOT IEHA
- Safety DP III to NASA

- SRP completion for SDP III at NASA



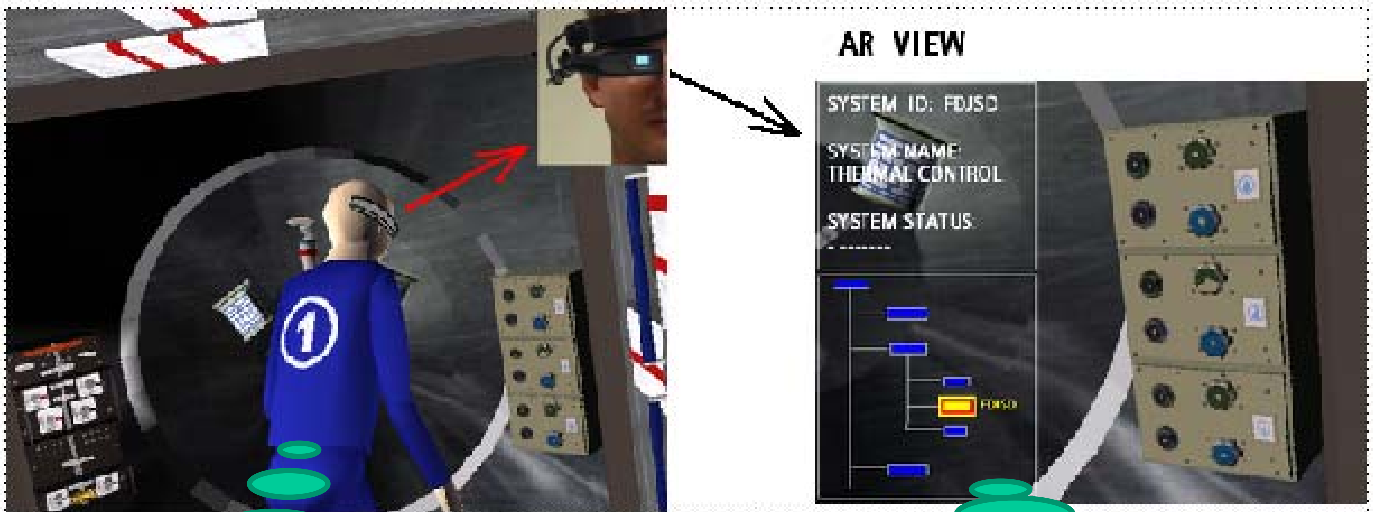
STS-128 / Flight 17A Upload WEAR Hardware

WEAR demonstration Sessions

Potential Benefits to the ISS Programme

- **Save crew time and increase efficiency**
  - Allowing hands-free operations and consultation of manuals and technical information.
  - Avoid moving to different workstations to gather required information
  - Integrate IMS with internal data sources, further facilitating information retrieval
  - Data that is relevant to procedures is presented to the crew Just-In- Time (JIT) and Just-In-Place (JIP).

WEAR User Interface



Speech interface: voice commanded, synthesized voice output

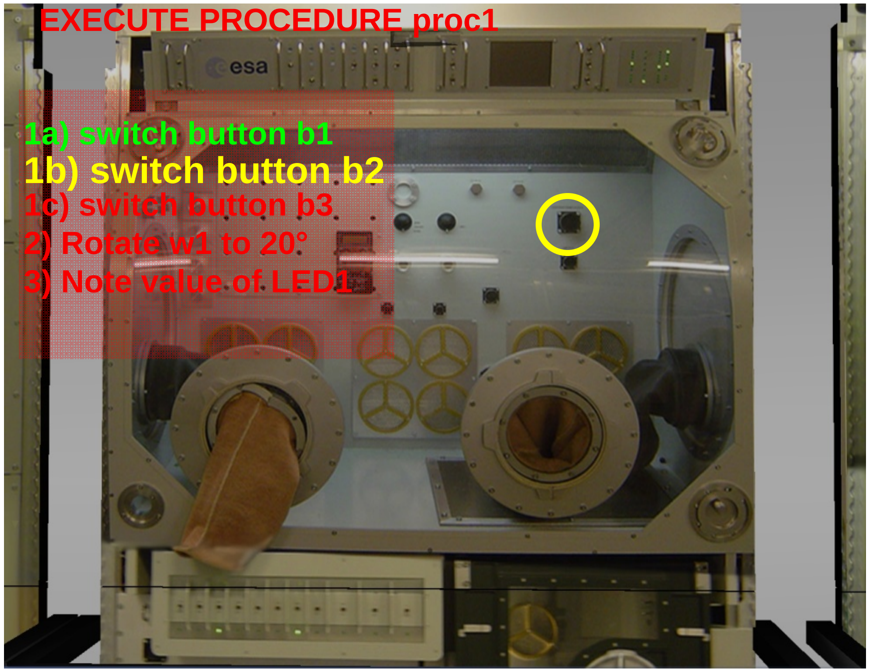
Automatic item identification from both barcode reading and object tracking by using the IMS database stored within WEAR.

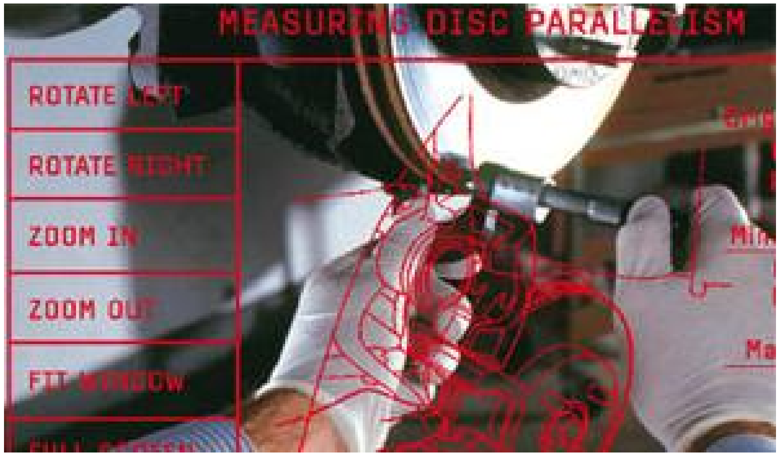
Usage Scenarios

Find equipment and show information on the equipment

Assist during procedures

View virtual 3D objects, superimposed on the real world






16. - 20. March 2009
esa
European Astronaut Centre esa
COLUMBUS SPECIALIST LEVEL & PAYLOAD TRAINING
FOR EXPEDITION 20

Videos

Challenges

- Change from R&D to Flight hardware
- Constraints:
  - Time (to develop, available for testing & experimentation)
  - Logistics (access to enviroment, transportation,…)
  - Environment conditions (noise, light, ..)
  - Use of the COTS, in very specific application
- Technology:
  - Localization technology
  - Required performance
  - Calibration

Preliminary results

- Crew was happy with hands free and usability of the system
- AR Calibration should be simplified
- AR Benefits depends on achievable performance

Thank you

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Backup Slides

Primary Objectives (1/2)

- The application of this SDTO onboard the ISS will demonstrate the advantages of natural interaction and augmented reality provided for crew operations by a portable device.
- The technology:
  - is able to interact with crew using voice recognition and intuitive visualizations;
  - is able to do object recognition and tracking, allowing context-specific information to be shown.

Primary Objectives (2/2)

- **Assess the overall performance of WEAR within Columbus in a demanding environment to support complex operations**
  - Determine the accuracy of the Speech Recognition technology by interpreting spoken inputs in the noisy ISS-environment
  - Assess the object recognition and tracking capabilities of WEAR in strenuous conditions caused by the random orientation in micro-gravity and the multitude of catalogued objects
  - Use information retrieval (barcode reading, object recognition, speech input, IMS database selection) and representation techniques (visual and using Speech Synthesis technology) for assisting in hands-free operations

Secondary Objectives (1/1)

- **Test the non-obtrusiveness and usability of the WEAR hardware on ISS in zero-gravity.**
- **Get a subjective appreciation of the system by the operators and acquire:**
  - Future needs by proposing usage scenarios
  - Usability feedback
  - Performance assessment and resulting improvement proposal
- **Use external means such as onboard audio and video recording equipment for recording usage patterns for later analysis**

Speech Recognition Issues and Mitigations

- A critical feature of WEAR is the speech recognition. Without this capability WEAR is unusable.
- Possible issues:
  - acoustic noise levels too high
  - speech interference of other crew members
  - malfunctioning microphone
  - inability of the crewmember to talk clearly into the microphone
  - software malfunction
  - incorrect procedure definition, resulting in spoken commands not being recognized
- Mitigations:
  - acoustic conditions will be assessed during pre-flight testing
  - crew training will teach the crewmembers how to use the speech recognition most efficiently
  - the speech recognition engine can be trained. More training, before or in-flight, results in better performance
  - WEAR only listens to the smallest possible set of commands that are currently relevant, limiting the chances of miscomprehension. Upon request, the system shows the current list of understood commands
  - in case of serious speech recognition issues, a fallback scenario exists in which only a very limited set of commands is understood, at all times. These commands will mimic mouse-pad usage. This fallback has an adverse impact on the performance though
  - in case of catastrophic failure of the speech recognition system (completely malfunctioning hard- or software), WEAR can be used using a hands-on approach, i.e. using the interaction features of the LTU. This severely impacts the usability and is therefore only a last resort

How does the WEAR Camera supports the Search?

In addition to the voice recognition function the function of the camera will be to take pictures.
These pictures will serve two main uses:

- The search input will also come from the camera. The idea is that if the system finds a barcode (and barcode reading is enabled), that barcode is immediately compared with the IMS and 'readable' information is shown to the crew. Even if the system is unable to continuously scan for barcodes (for performance reasons) and the crew has to manually say something like 'scan', it is still the camera related software that finds the barcode and retrieves data from the IMS.

- The pictures taken from the camera will serve as follows:
  - after the software adds the AR to the pictures, they are saved into the internal WEAR database. These pictures can then be used for example for logging and reviewing a procedure after has been completed. In other these pictures are snap-shots.
  - the barcode reading software will use the same pictures to extract barcodes in the field of view. These barcodes are then matched to equipment in the IMS with an internal WEAR database.
  - the pictures are also used by the object recognition and tracking system.

Evaluation of WEAR

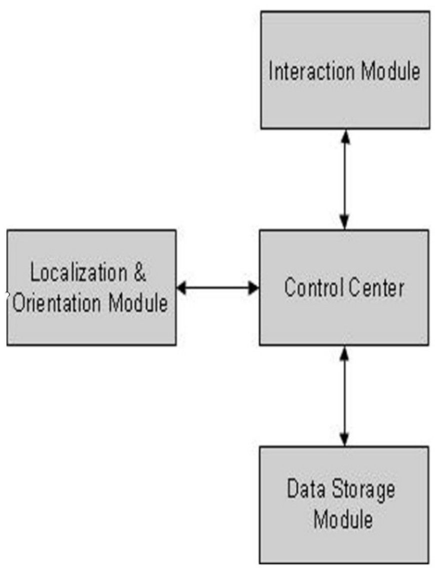
- **Quantifying the benefit**
  - Objective comparison with historic data
    - average execution time with & without WEAR
  - Subjective appreciation of crew via questionnaire
    - perceived ease of use
    - perceived increased or decreased risk of making mistakes
    - perceived increased or decreased physical or mental strain, in comparison to current methods
    - willingness to reuse the system

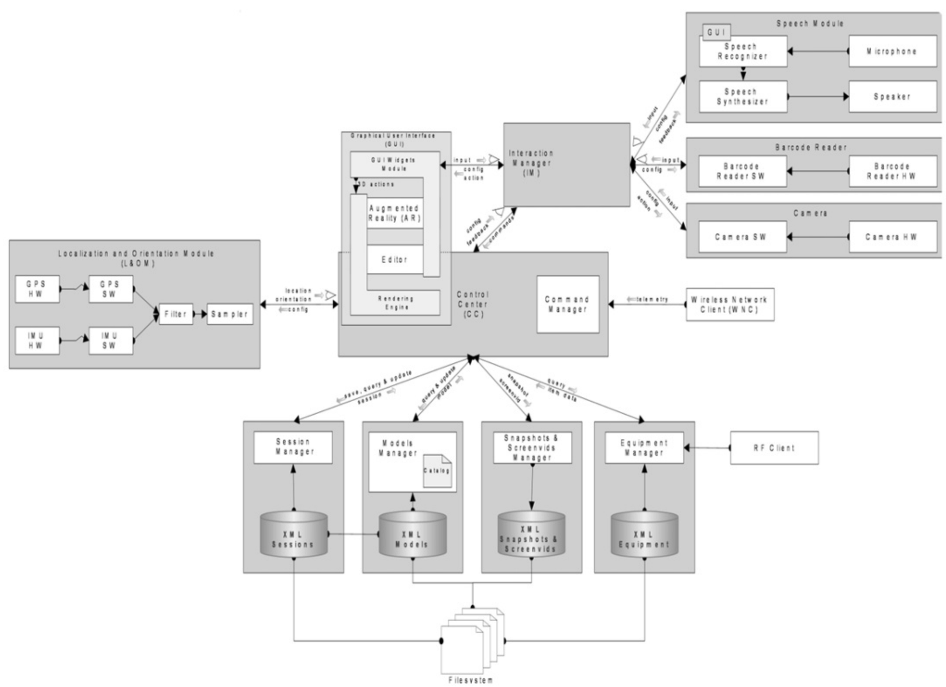
Overview of Technology

- Operating System: (Windows XP)
- Speech Recognition and Synthesis: (Microsoft Speech API)
- Computer Vision Based System for pose determination and object recognition and tracking: (development in collaboration with KUL)
- GPS and IMU sensors for localization, position and orientation tracking: (Xsense MTi-G)
- Barcode Reading: (image processing/scanning)
- Scene Rendering: (OpenSceneGraph)

Overview of Software Design

- Loosely coupled modular, event-based, design
- Using available libraries: WxWidgets (GUI), OpenSceneGraph (Rendering), Boost (utils), Sedna (XML-db), …

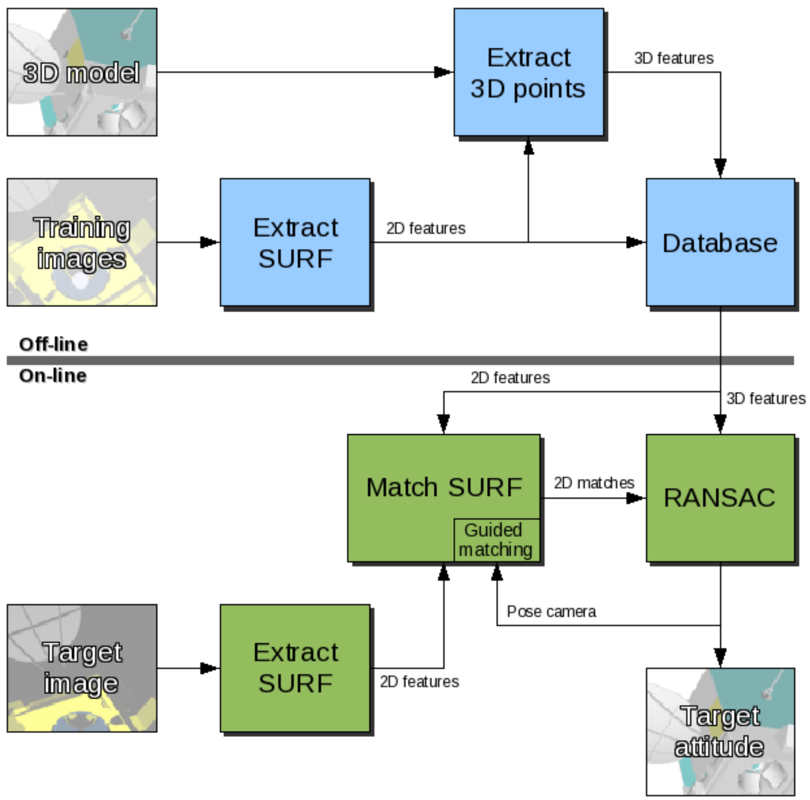




Computer Vision Pose Tracking Technology

- based on extraction of image features using SURF[1] algorithm invariant to:
  - in-plane rotation
  - scale changes

  robust to:
  - out-of plane rotations
  - illumination variations
- RANSAC[2] algorithm used to filter outlying matches



1 (Speeded Up Robust Features)
2 (Random Sample Consensus)

Courtesy of KUL

Challenges

- Drift of IMU: Error accumulates and accuracy decreases with time
- Computer Vision based sensing and IMU sensing are very complementary:
  - Vision based sensing process is time consuming and can only provide update at low rate (~10 Hz) but is very accurate (1 pixel)
  - IMU is capable to follow fast movement as it senses at a high rate (~100Hz) but it drifts very quickly
  - Vision based sensing can be used for regularly recalibrating the IMU
- As a solution, a tightly coupled system is built by fusing both types of sensors through an EKF. Accuracy should be kept ~1cm/ ~1deg.
- Robustness of Speech Recognition System in noisy environment

Operational Evaluation

- Operational Evaluation performed by Belgian astronaut Frank De Winne in two sessions in September and October 2009