mur.sat

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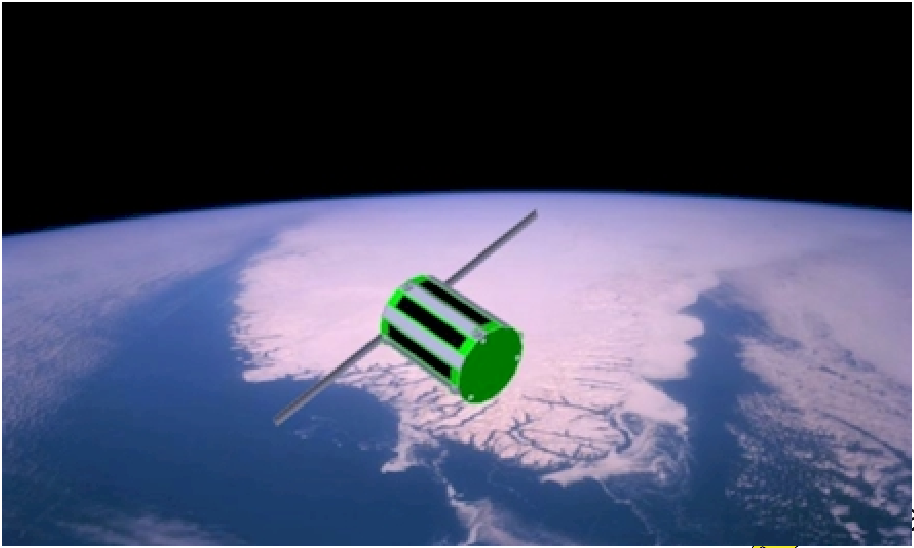
14. August 2011

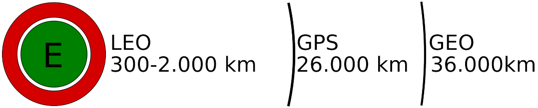
Outline

The Goal



©Picture IOS

The Beginning



- We read the news:
  - Interorbital Systems (IOS) offers cheap picosatellite launch and dev. kit
  - Deployment using self-built Neptune rocket (still in dev.)
  - about 32 sats / launch into LEO ($\approx$ 310 km)
  - TubeSat Kit+Launch: $\approx$ 8000 *USD*
- We wanted to participate
- We bought the kit
- We started reading up on stuff

Early Ideas

- Radioscanner
- HAM radio relay
- Send messages to earth
- Send messages from earth to space
- LED-Laser-Sky-Graffiti
- Magnetic orientation sensor (real-time visualization of satellites' orientation)
- Poor man's space travel
  for Euro 250,– we take your hair to space

TubeSat Kit Arrived

TubeSat Kit

- Gerber files / PCB schematics
- Battery 5200 *mAh*
- Sample ejection cylinder
- 50 small solar cells
- Specialized distance-holding screws
- Microhard modem 2.4 GHz

Ordering Some More Components

The current plan

- Piezo-electric microphone
  - Particle detection
  - Audio samples from space
    (thermal expansion/contraction, radiation, . . .)
  - Soundarts
- Counting, Noise Artist GX Jupitter-Larsen
  - Alien n-counter
  - Beacon counter
  - Counting illumination changes in photo diodes (satellite rotations)

What it Does (cont'd)

- Camera: Pictures from space or earth (preferably both)
- Kids' text messages put in store and broadcast
  - Kids' wishes (stored in flash), become itself a new shooting star
  - 2 *kiB* compressed European culture as audio data
  - Broadcasts of messages as energy budget allows
- All data (that we manage to receive) will be open and freely available

A Typical Meeting (Communications Group)

Experience at the Camp

- Talk with experienced satellite builders (AMSAT-DL)
  Thank you Mario !!
- Newfound desire to redesign a lot of IOS reference designs
  - Antenna
  - Power system
  - Transceiver and modem
  - Basically everything but mechanical design

Listening to Satellites

- Became regular team event
- Getting feeling for satellite radio communications
- Is actually not that easy
- Future events will be live on Radio Helsinki (`helsinki.at`)

. . . in Style at the Camp

Bureaucracy

- ITU / AMSAT, frequency allocation
- IOS, proving launch capability to incr. heights within 2011
- Registering satellite with country or UNO
- New Austrian law for satellites
  insurance of at least 60 million Euro payout required
  hopefully not for us . . .

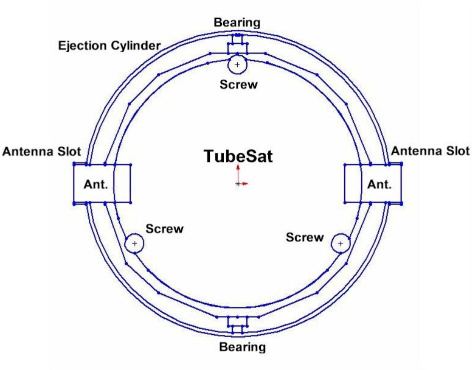
3, 2, 1, . . . Lift-Off

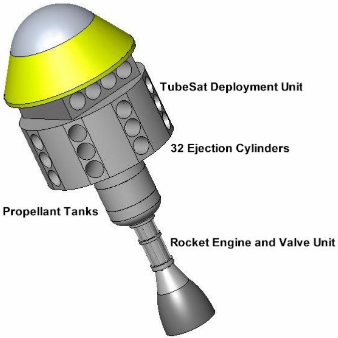
1. „Launch“ from Graz, with postal service

2. Party will follow :-)

Outline

Launch Vehicle

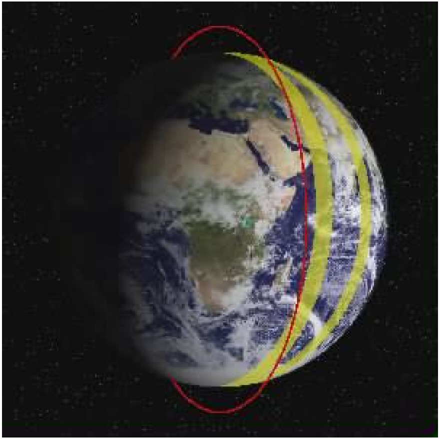




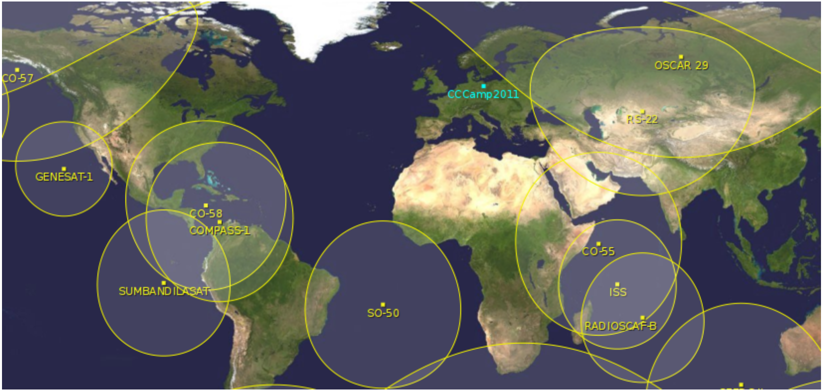
- Neptune (N45) – TubeSat-Deployment-Unit
  - Currently under development
  - Mojave desert in the southeast of California

Polar Orbit

- Polar LEO
- Orbital period $\approx$ 90 *min*
  $\Rightarrow \approx$ 310 *km* Height
  $\Rightarrow \approx$ 22.5 ^{o} / Orbit
- At 60 ^{o} access region
  $\Rightarrow$ 1 – 3× / day&ground station
- Atmospheric friction
  $\Rightarrow$ Orbit decay
  $\Rightarrow$ Mission duration: 0 – 6 *Weeks*



Satellite Access Window



screenshot of gpredict

- Sat moves fast: $\approx 28.000 km/s \approx 7777 m/s$
- Rather short contact time: $< 10 min$

Stuff to Guard Against (and not)

- Mechanical stress during launch
- No convection in vacuum
- Broad range of temperatures
- Hardware faults
- Software errors
- Transceiver drift (emergency switch-off)
- Gases trapped in components or soldering

Stuff we ignore:

- Battery lifetime reduction (through environmental factors)
- Radiation (at least most of it)
- Extreme temperatures ($< -40\ ^oC$ or $> 100\ ^oC$)

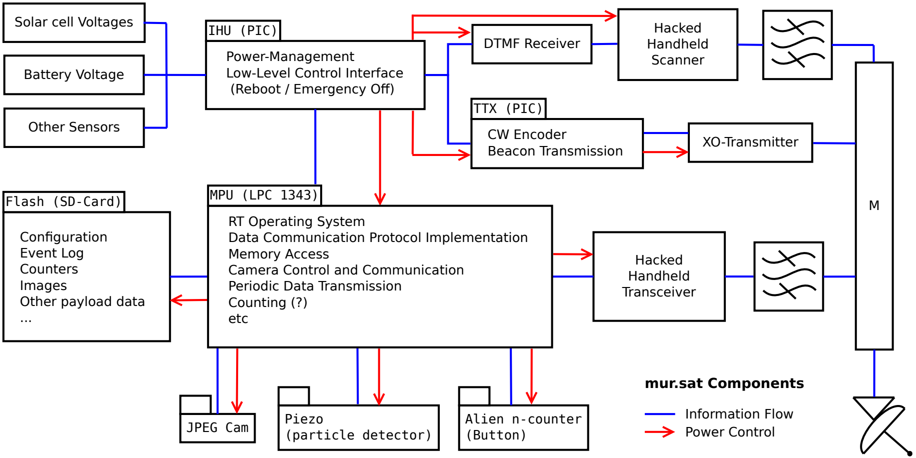
Outline

Weight Budget

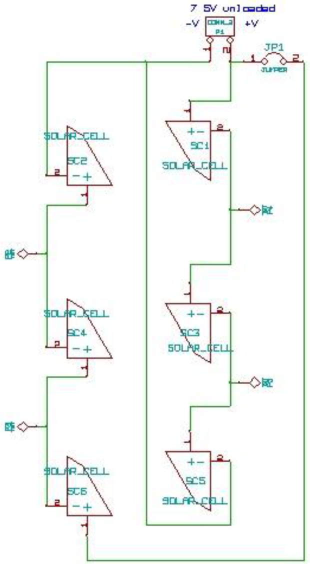
Maximum Weight: 0.750kg

150g	Mechanical structure (incl. PCBs, Antenna)
50g	Li-Ion battery 5200 mAh
120g	Hacked hand-held transceiver
80g	Hacked hand-held scanner
100g	Electronics
500g	Total
250g	left for Payload

Component Chart



Power Supply



©circuit by IOS

Estimated Solar Power:

- per cell at optimum angle to sun:
  - $\approx$ 28 mA @ 2,2 V
- per solar cell strip:
  - 3 serially connected cells, 2 of those in parallel
  - $\approx$ 56 mA @ 6,6 V
- Total:
  - at most 3 solar cell strips in sunlight
  - max $\approx$ 168 mA @ 6,6 V or $\approx$ 1100 mW
  - real $\approx$ 500 mW (we hope)

Dynamic Energy Management (IHU)

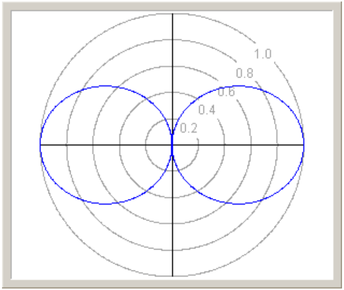
- IHU calculates energy levels
- Energy gets divided into tokens
- MPU gets an amount of tokens (energy) for given time
- MPU may use tokens for several tasks
- MPU knows how many tokens a task consumes
- MPU is not allowed to save tokens

Antenna Gain

- Dipole antenna
- Donut-shaped emission
- Theoretical gain: 2.2*dBi* @70*cm*

Problem:

- Attitude: basically unknown
  → Unfavorable antenna angle very possible
- Rate of rotation: unknown
  → Signal fading



Radiation pattern,half-wave dipole, LP@WP

Communication Channels

2*m* (145.9 *MHz*, VHF)

- bandwith up to 12 *kHz*

CRX Control RX

70*cm* (435 *MHz*, UHF)

- bandwidth up to 40 *kHz*

TTX Beacon, telemetry data

RX/TX Downloading accumulated data

CRX: DTMF Emergency Commands

- Sent using DTMF over FM
- Receiver listening for $> 200ms$ every $5s$
- Generates interrupt on IHU
- ITU requirements force us to implement at least an emergency rfkill ("shut up") command

TTX: Beacon

- CW (morse code)
- Beacon every $\approx 60s$
- Immediate ACK of an DTMF Command

Example (CW Beacon Content)

#C	Desc
1	Start Character
4	Call Sign
3	Beacon Counter (base32)
1	State (base32, bitfield)
1	Number Cmds in Queue
...	Voltages, Temperature, EnergyTokenAmount
...	
1	Checksum Parity Sign

RX/TX

- Robust against fading, FEC, standardised, high throughput
  - Still considering several candidates
- Avoid bidirectional communication
  - Implement command queue
  - Tell sat what to do
  - Then just listen
- Some regions: only listeners, no uplink to start communication
  - Schedule transmissions beforehand

Example (Commands)

- Clear CmdQueue
- Append Command XXXXWaitDuration (e.g.)
- Execute CmdQueue (#cmds, MAC(#cmds++full CmdQueue,secretKey))

MPU – Payload Hardware

- CPU: LPC-1343, ARM Cortex-M3
- CMOS camera
- Orthogonally mounted light-sensors
- Button (Alien n-counter)
- Piezo-electric microphone

Image Quality Decision

- Before picture is taken
  - Test if light conditions favorable (photo diodes)
- After picture was taken
  - File size ≈ information measure
  - Look at highest order DCT coefficients
    - Compressed YCbCr histogram
    - DCT-mean, DCT-StdDev
  - Problems
    - Image noise

Testing

- Vacuum test chamber
- Vibrating table
- Battery and components at $-40\ ^oC$ to $100\ ^oC$
- Radiation ? $\rightarrow$ will be ignored
- Balloon test launch


WARNUNG!

- Buy a T-Shirt
- Visit Us
  - LeiwandVille
  - HamVille Corner
  - below the big shortwave antenna
- Talk With Us