# *A Snapshot GPS Approach for Precise Positioning and Attitude Determination of MicroSatellites*

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# *Small Satellite Design Trends*

- Large satellite >1000kg
- Medium sized satellite 500-1000kg
- Mini satellite 100-500kg
- Micro satellite 10-100kg
- Nano satellite 1-10kg
- Pico satellite 0.1-1kg
- Femto satellite <100g

**Small Satellites**

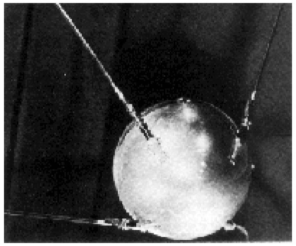
# Advantages of Small Satellites

- Low investment and operational costs
- Flexibility in design approach
- Short systems development cycles
- Lower launch costs
- Leveraging COTS technology
- Typical microsat costs <$10M in orbit

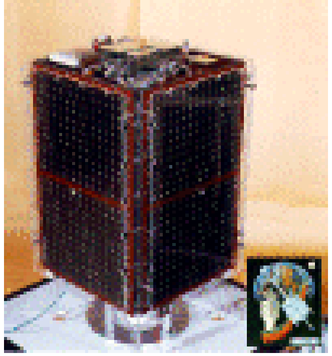
Over 400 microsats have been launched in last 20 years

# *Examples of Small Satellites*

- Sputnik (1957)
  - 84 kg
  - Radio transmission



- PoSAT-1 (1993)
  - 50 kg
  - GPS, Earth Imaging System, Star Sensor, Cosmic Ray Experiment,



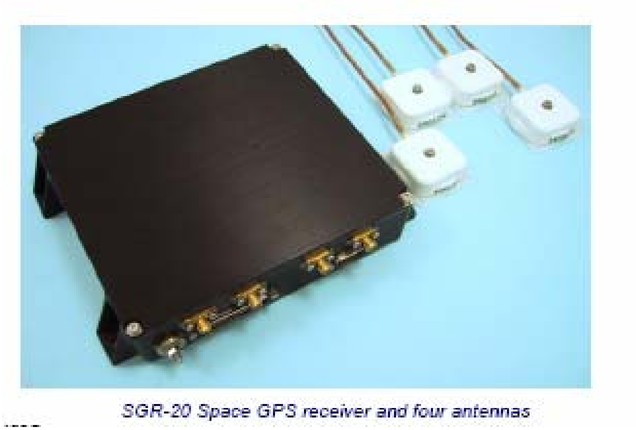
- GeneSat-1 (2006)
  - 10 kg
  - Biological payload, 437 MHz Beacon, 2.4 GHz comms

# *Small Satellite Design Challenges*

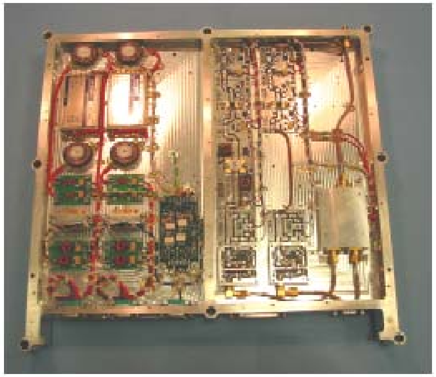
- Minimize size, weight, power and cost of onboard avionics and payloads
- Positioning and communication functions are needed to support orbital operations
- COTS commercial GPS solutions do not work well in a space environment
- Custom designed space GPS solutions are large and expensive
- Using a SDR allows sharing of resources for positioning and navigation

# *Challenges for Space GPS Receivers*

- Hardened electronics and processors
- All-around visibility
- Low cost (typically $50-$350 K currently)




SGR-20
(0.95 kg)

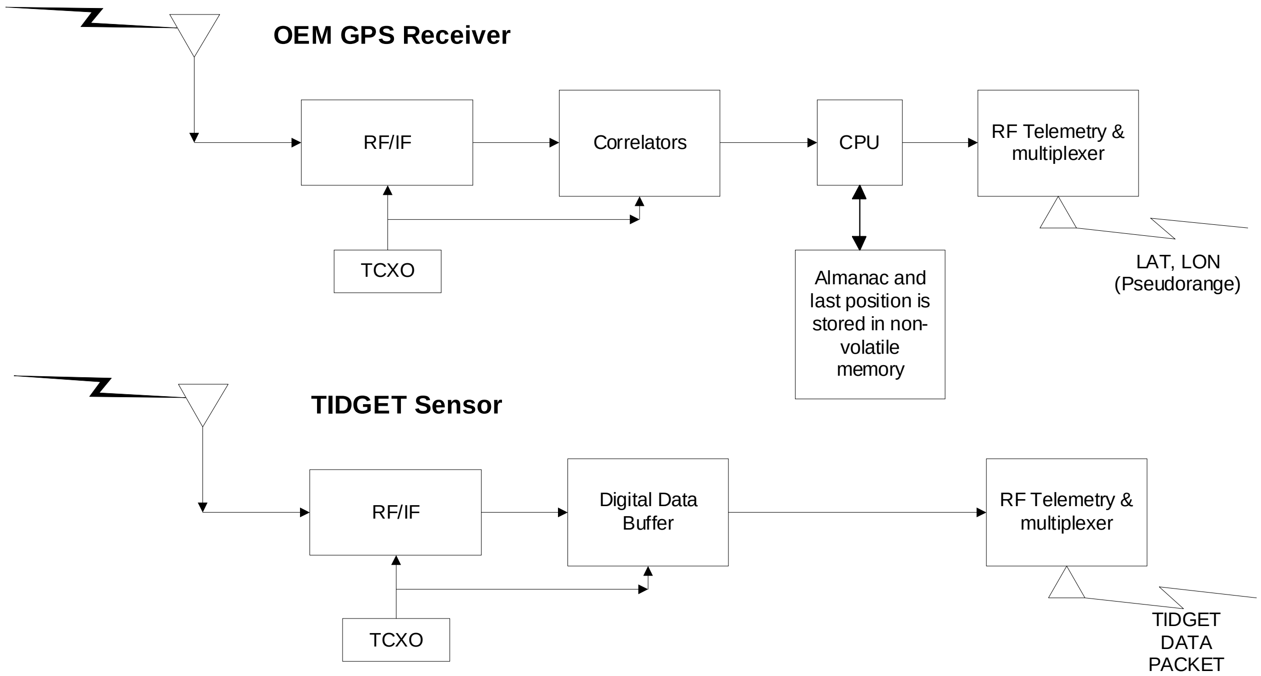


UHF Transmitter
(2.5 kg)

Computer
(1.7 kg)

# Prior Software Defined Radios with GPS Processing


# Networked GPS Positioning Solution

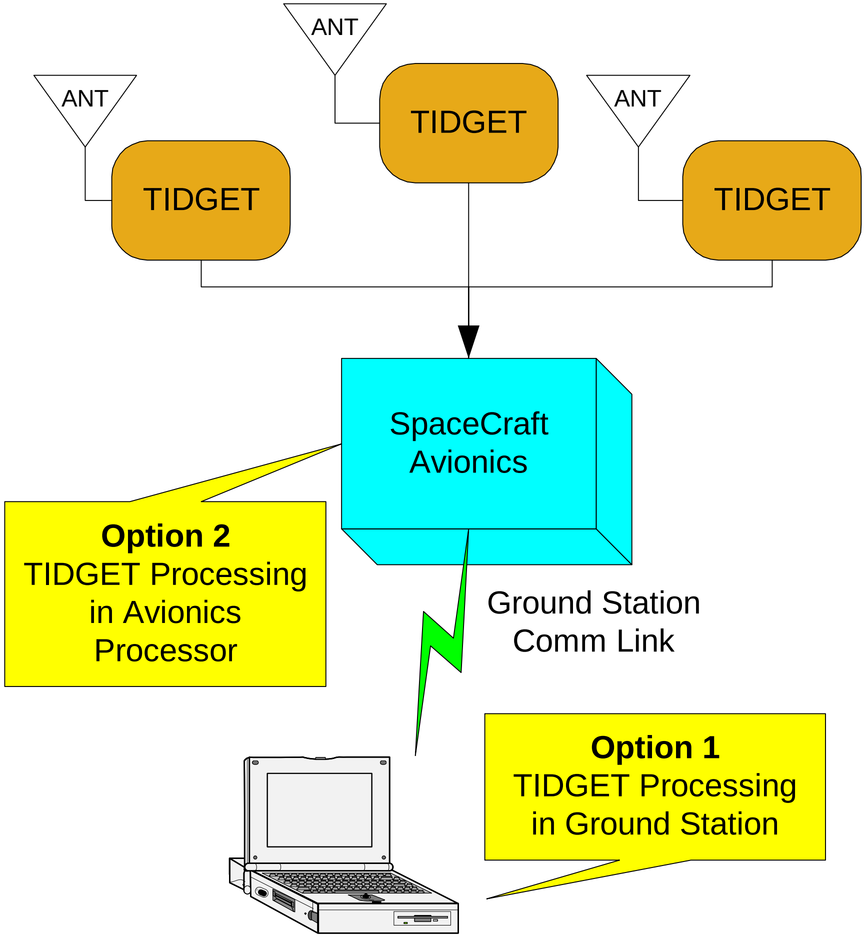



TIDGET "Tracking Widget" collects GPS data to be processed by Software Defined Radio

# Space TIDGET Architecture

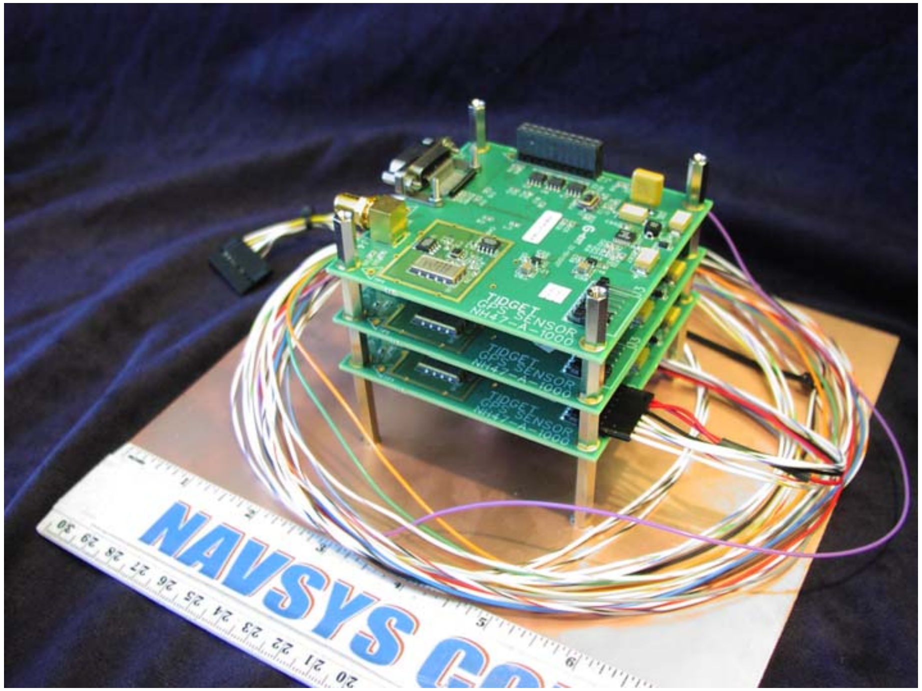
## Advantages

- TIDGET sensor includes only hardened GPS RF electronics
- Multiple TIDGET sensors provide all-around visibility and attitude determination
- Processing performed using SDR in Ground Station or onboard Processor



# Space TIDGET Hardware

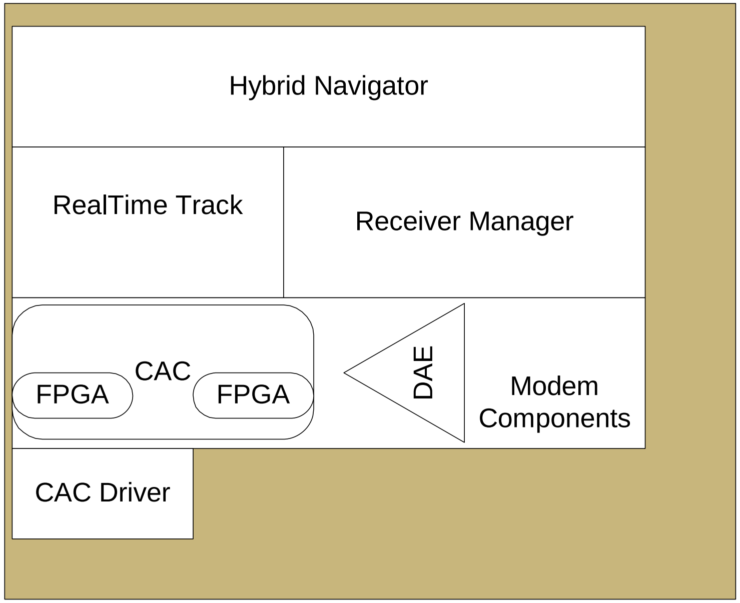
- Sensor stack
  - 3 TIDGET circuit boards (1 Master, 2 Slaves)
- Connectors
  - Avionics host (power, control, data)
  - GPS antenna
  - Stack-thru connector

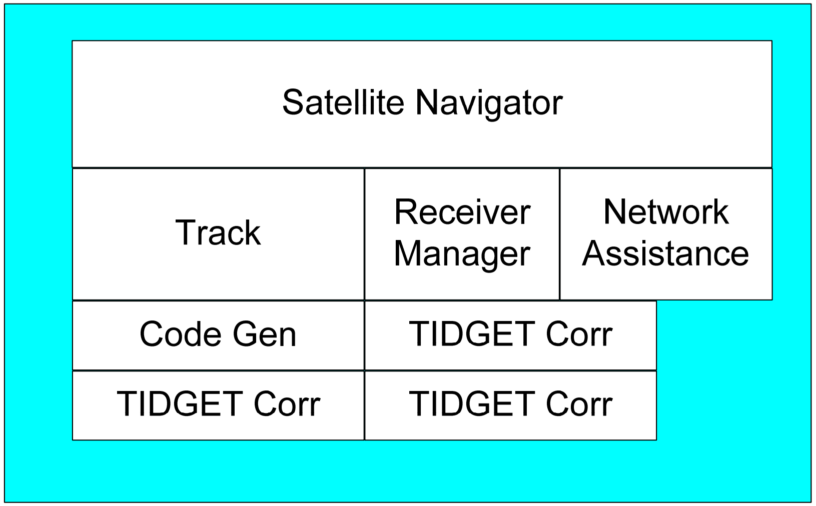


# *TIDGET Sensor Stack Features*

- Low power Design
  - Circuitry powered on and off by CPLD logic
- Common Timing
  - Precise sync between units allows for both position and attitude determination
- Hardened electronics
  - Extended temperature range commercial parts
  - TCXO specified for high vibration/shock
- Built in redundancy through SDR processing

# Conventional Software GPS vs TIDGET Processor




Software GPS Receiver
SW Components

TIDGET Processor
SW Components

# GPS Signal Sampling & Correlation

<u>Conventional SGR</u>

- FPGA used to generate code and carrier
- Real-time search, acquisition and tracking
- Multiple channels used to handle different GPS satellite signals and Receiver RF inputs

<u>TIDGET Processor</u>

- Code generation performed in SW
- Uses SV orbit to preposition code/freq
- Only single set of code/carrier reference needed for all 3 TIDGET sensors

# GPS Satellite Tracking

## Conventional SGR

- Each individual channel independently tracks one GPS satellite and one RF input
- Generates Pseudo-Range (PR), Doppler and Carrier Phase (CPH) for each GPS SV/antenna pair

## TIDGET Processor

- All 3 TIDGET sensors processed in parallel
- Tracking loops estimate composite SV Pseudo-range and Doppler and estimate delta-PR and delta-CPH for each sensor
- Improves reliability of lock detection and tracking through signal fades

# GPS NAV Data Collection

Conventional SGR

- SGR demodulates NAV data to unpack GPS ephemeris
- Used to calculate GPS position and velocity

TIDGET Processor

- GPS ephemeris data obtained from ground network
- Can be uploaded daily or more frequently
- Also can improve accuracy using Precise GPS Ephemeris (PGE)

# GPS Navigation

<u>Conventional SGR</u>

- Uses Kalman Filter or Least Squares to estimate position and velocity (stand-alone)
- Hybrid GPS/inertial solution calibrates error on inertial sensors

<u>TIDGET Processor</u>

- Navigation filter estimates position, velocity and attitude of spacecraft orbit
- State propagation performed using orbital dynamics rather than inertial navigation unit

# *Advantages of Space TIDGET SDR Approach*

- TIDGET sensors are lighter, smaller and lower power than full GPS receiver
- TIDGET solution offers “on-demand” location and queued processing for resource sharing
- TIDGET/SDR architecture offers an inexpensive, modular positioning system
- Flexibility of SDR TIDGET processing optimizes GPS  performance for challenged space environment

# *Backup*

# Functions performed by SGR SW Components

| Component | Functions Performed |
| --- | --- |
| Modem - DAE | RF/Digital Conversion |
| Modem - FPGA | Code Generation, Correlation & Carrier Mixing |
| CAC Driver | FPGA interfaces (e.g. NCO settings and Correlator Outputs) |
| Real-Time Track | Real-Time Code & Carrier Tracking loops and NAV data demodulation |
| Receiver Manager | GPS SV position calculation and SV selection |
| Hybrid Navigator | Position/Velocity Calculation (Least Squares or Kalman Filter) |

# Functions performed by TIDGET Processor Components

| Component | Functions Performed |
| --- | --- |
| Code Gen | Code & Carrier Generation using Code phase/Doppler Prepositioning |
| TIDGET Corr | Code & Carrier correlation of TIDGET data |
| Track | Assisted Code & Carrier Tracking loops for all TIDGET sensors |
| Receiver Manager | GPS SV position calculation and SV selection<br>Code phase/Doppler Prepositioning with GPS/Satellite position/velocity |
| Network Assistance | Receives GPS NAV data through Network |
| Satellite Navigator | Position/Velocity Calculation (Orbital Kalman Filter) |