

# ***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**

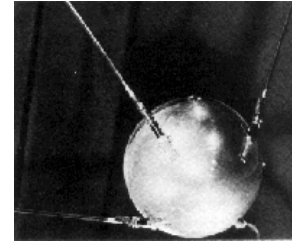
# *Advantages of Small Satellites*

- Low investment and operational costs
- Flexibility in design approach
- Short systems development cycles
- Lower launch costs
- Leveraging COTS technology
- Typical microsats 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

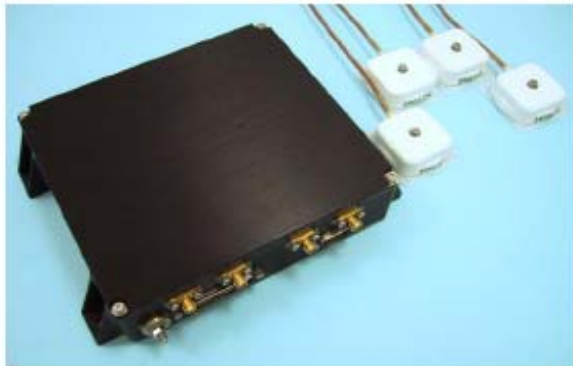


# *Small Satellite Design Challenges*

- 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

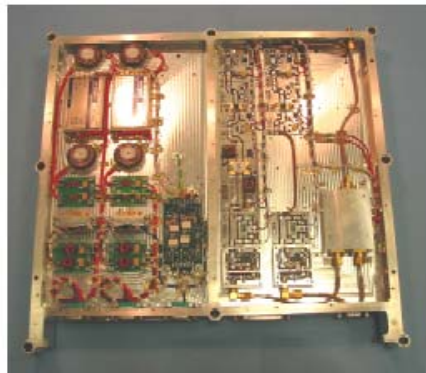
# Challenges for Space GPS Receivers

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



SGR-20 Space GPS receiver and four antennas

SGR-20  
(0.95 kg)



UHF Transmitter  
(2.5 kg)



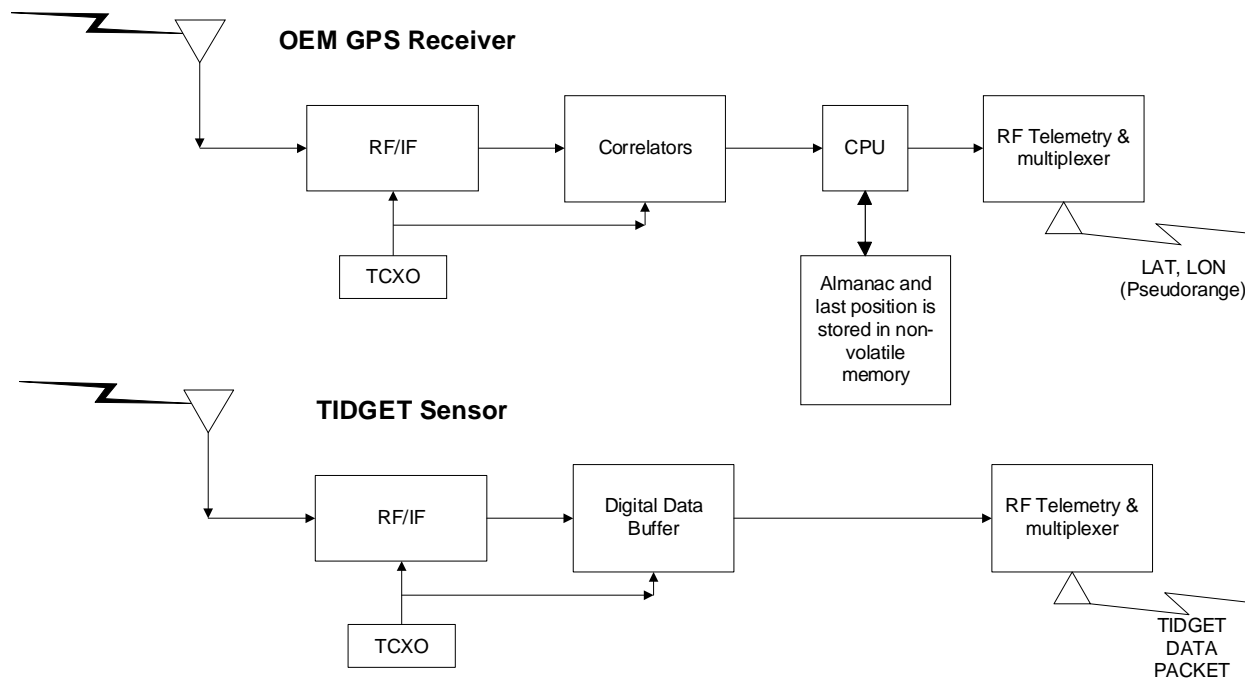
Computer  
(1.7 kg)



# Prior Software Defined Radios with GPS Processing



# Networked GPS Positioning Solution



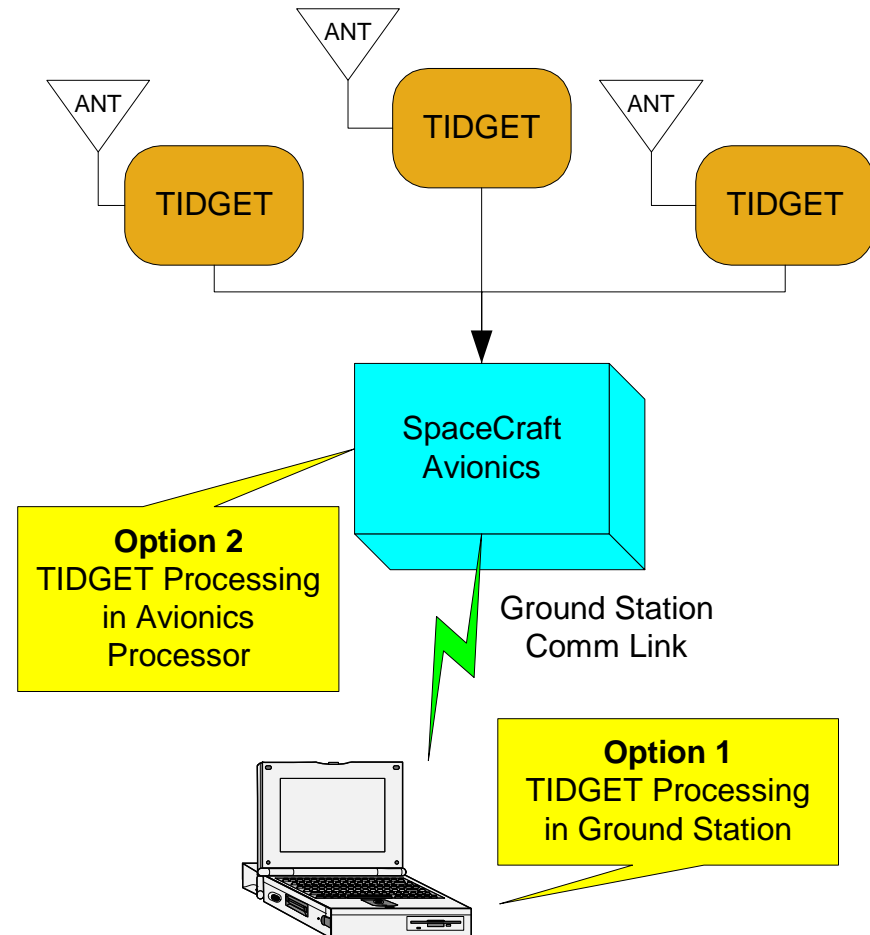
TIDGET “Tracking Widget” collects GPS data to be processed by Software Defined Radio



# Space TIDGET Architecture

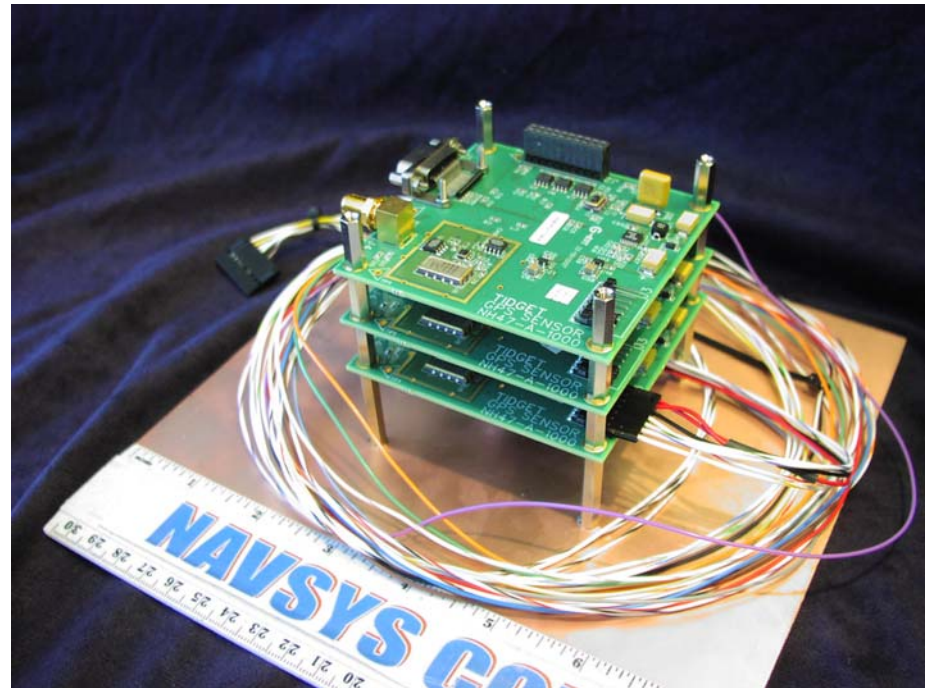
## Advantages

- 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

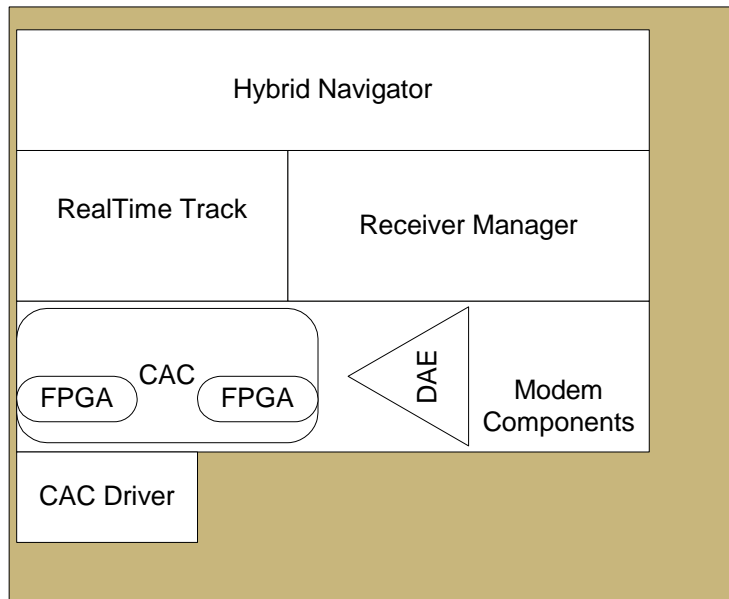
- Sensor stack
  - 3 TIDGET circuit boards (1 Master, 2 Slaves)
- Connectors
  - Avionics host (power, control, data)
  - GPS antenna
  - Stack-thru connector



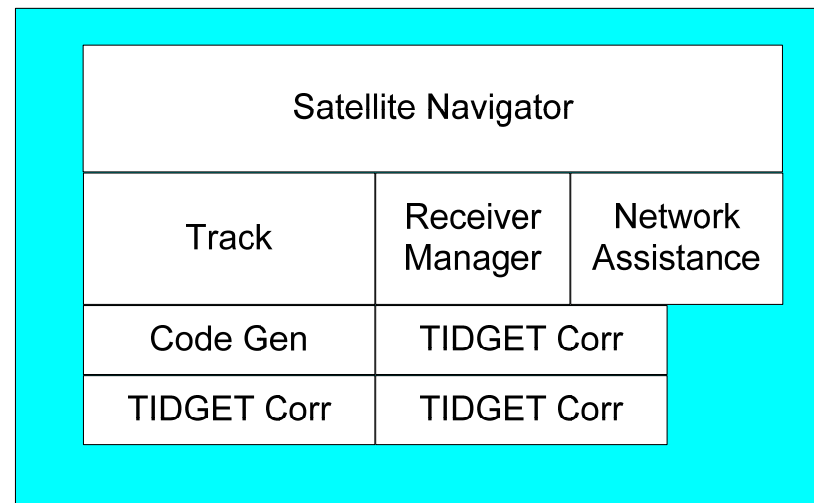
# ***TIDGET Sensor Stack Features***

- 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***

## Conventional SGR

- 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

## TIDGET Processor

- 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*

## Conventional SGR

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

## TIDGET Processor

- 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 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)