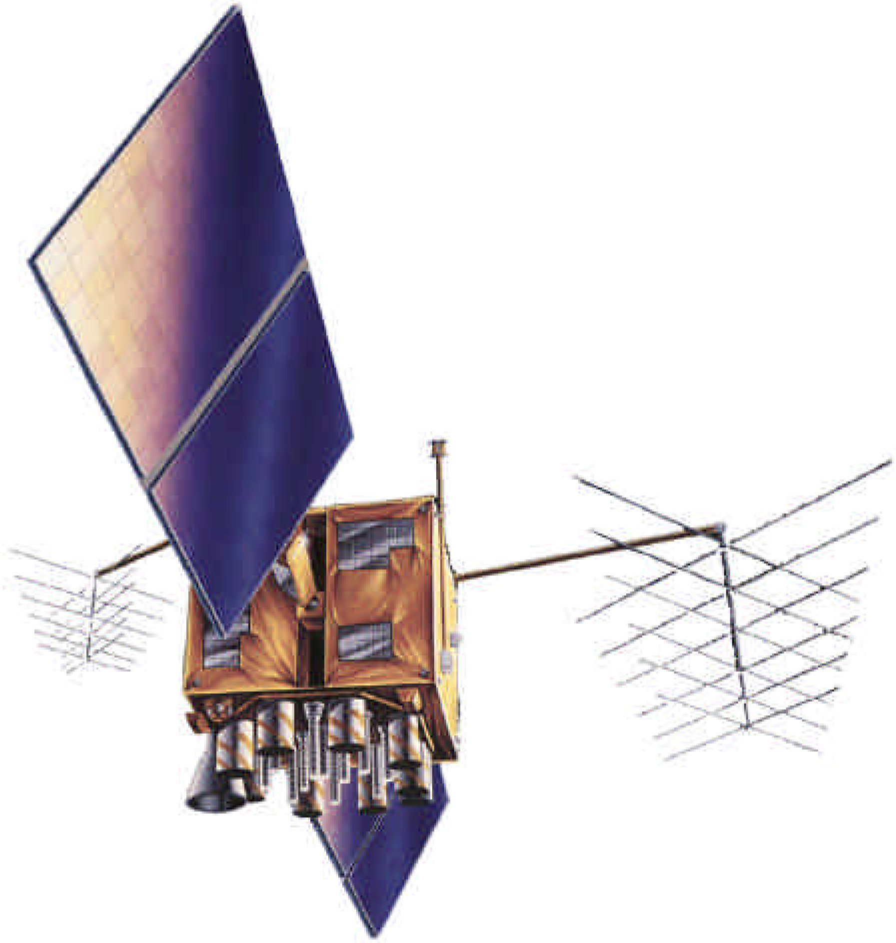
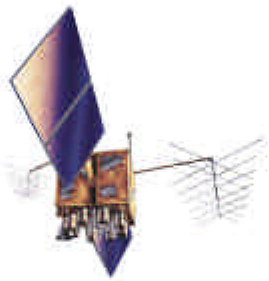


Using GPS in Embedded Applications

Pascal Stang
Stanford University - EE281

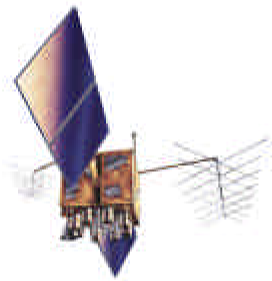
November 28, 2000



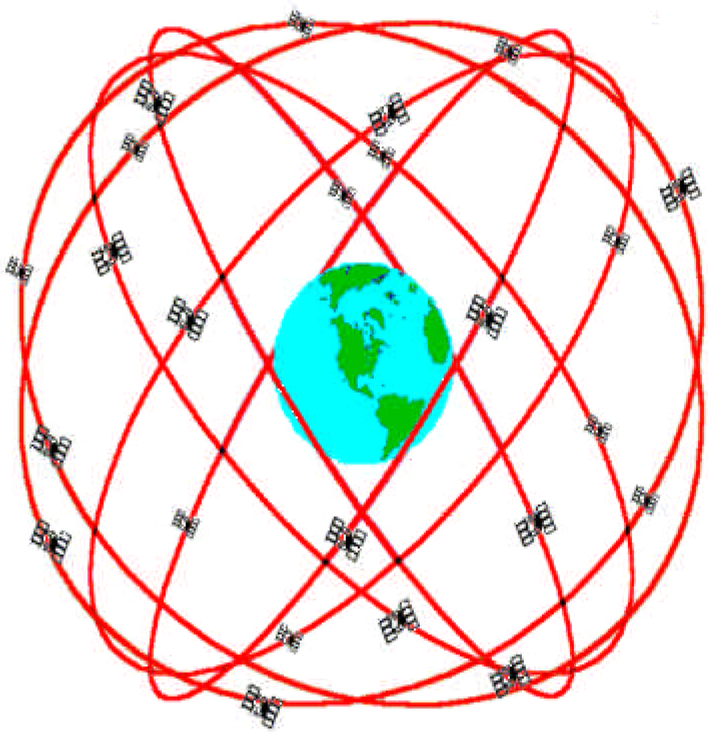
INTRODUCTION

- Brief history of GPS
  - Transit System
  - NavStar (what we now call GPS)
    - Started development in 1973
    - First four satellites launched in 1978
    - Full Operational Capacity (FOC) reached on July 17, 1995
    - System cost of $12 billion
    - GPS provides both civilian and military positioning globally
    - GPS comprised of three “segments”
      - Space Segment (the satellites)
      - Ground Segment (the ground control network)
      - User Segment (GPS receivers and their users)

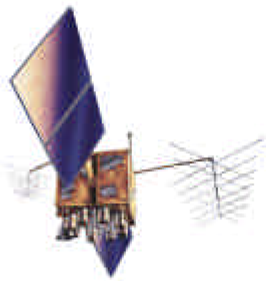
*Selective Availability (S/A) deactivated May 2000



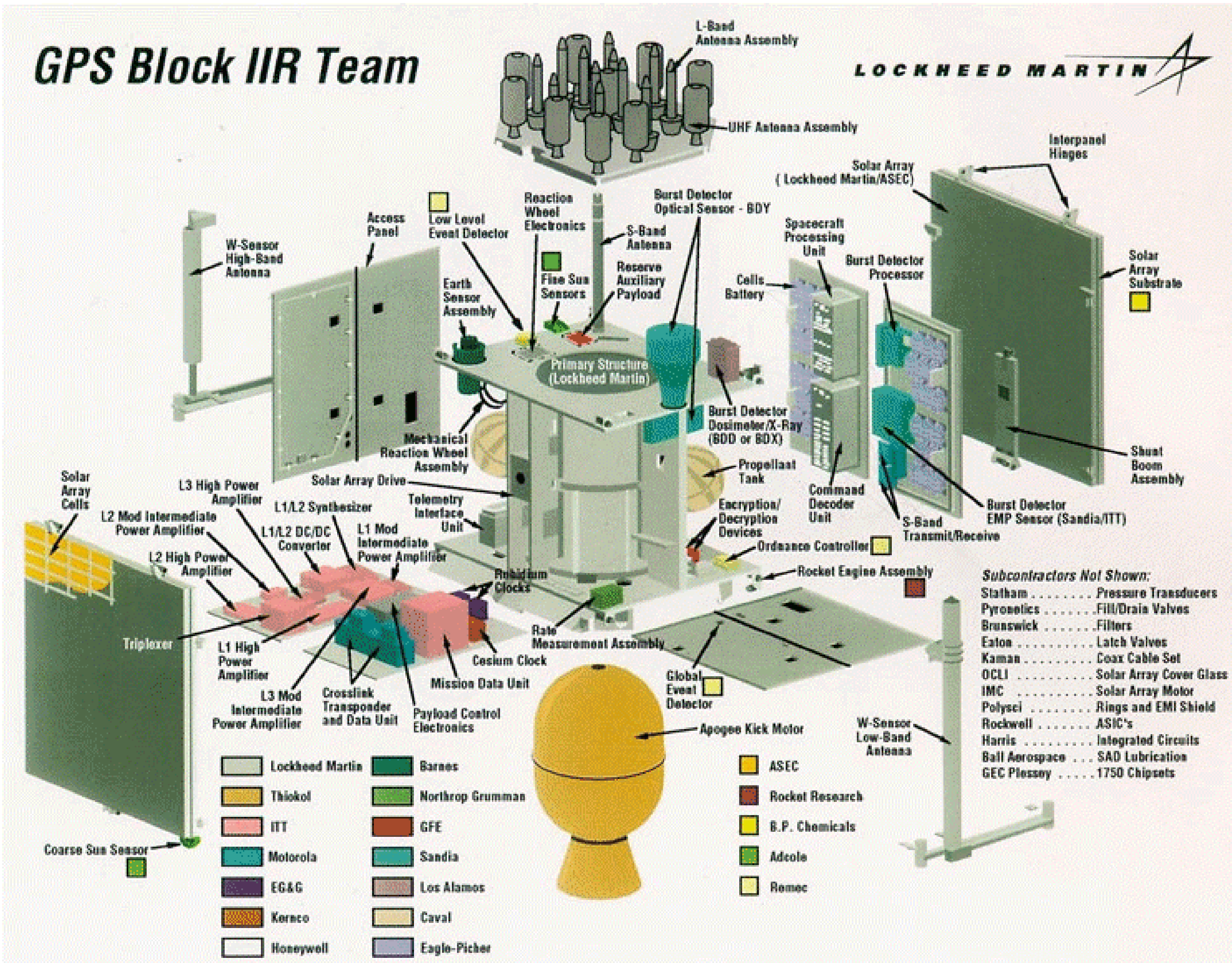
GPS SPACE SEGMENT

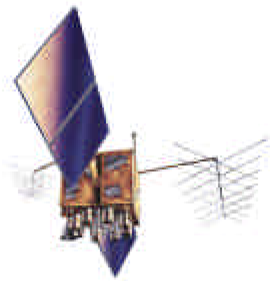


- GPS Constellation
  - 24 satellites (**S**pace **V**ehicles or **SV**s)
  - 20,200km altitude (12 hour orbit period)
  - 6 orbital planes (55° inclination)
  - 4 satellites in each plane
- GPS Satellite Details
  - Manufactured by Rockwell International, later by Lockheed M&S
  - ~1900 lbs (in orbit)
  - 2.2m body, 7m with solar panels
  - 7-10 year expected lifetime

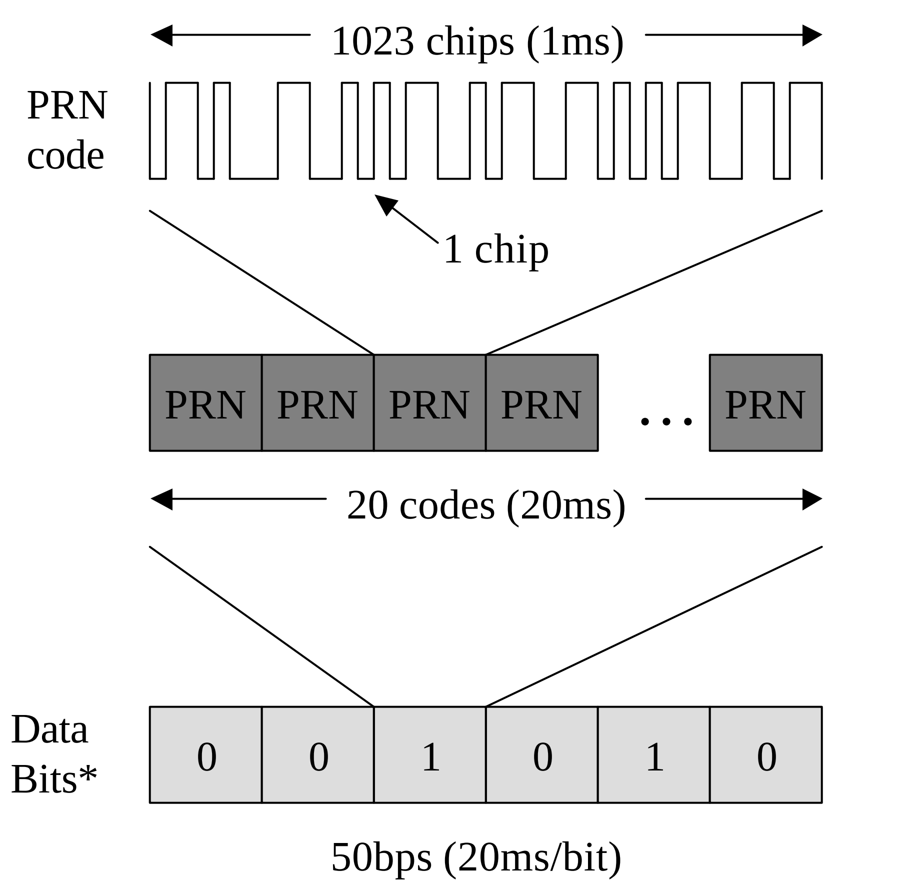


GPS BLOCK IIR SATELLITE





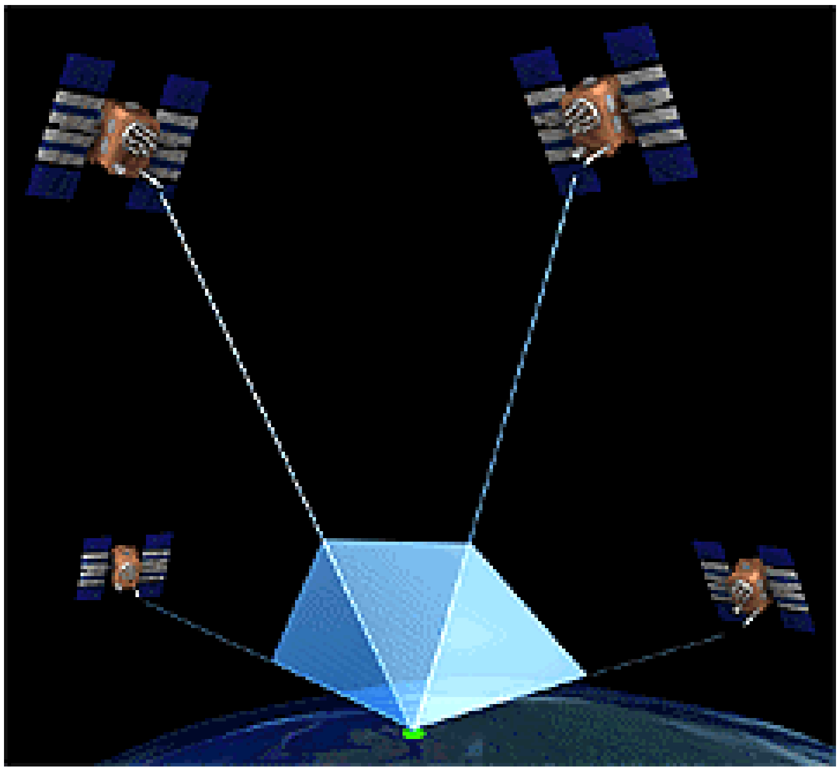
The GPS Signal



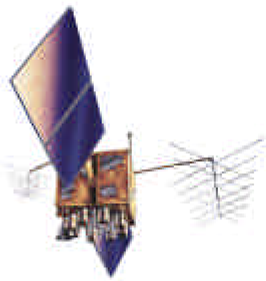
*PRN code inverts to signify bit transition (0/1)

- C/A code and P(Y) code
- All SVs transmit at 1575.42MHz
- Each SV modulates using a unique 1023-bit pseudorandom (PRN) code sent at 1.023Mcps (chips per second)
- PRN allows spread-spectrum CDMA management of GPS transmit frequency
- Receiver's distance to the SV can be determined by measuring the PRN time skew between the transmitted and received signals
- GPS system data (ephemeris, clock, and atmospheric parameters) are transmitted by further modulating the PRN code at 50bps

How To Get A Position



- Need signal from at least four SVs for 3D position
- One SV provides a time reference
- Distance to three remaining SVs is determined by observing the GPS signal travel time from SV to the receiver
- With three known points, and distances to each, we can determine the GPS receiver's position (trilateration)

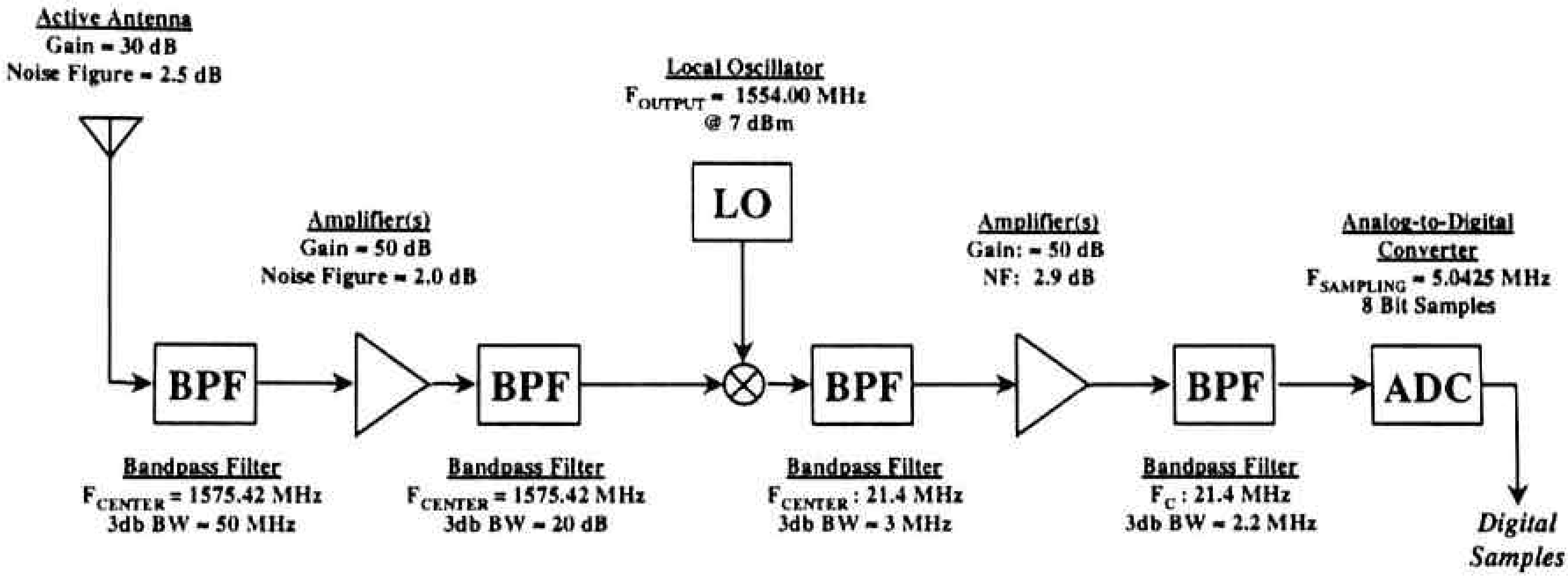


EMBEDDED GPS RECEIVERS

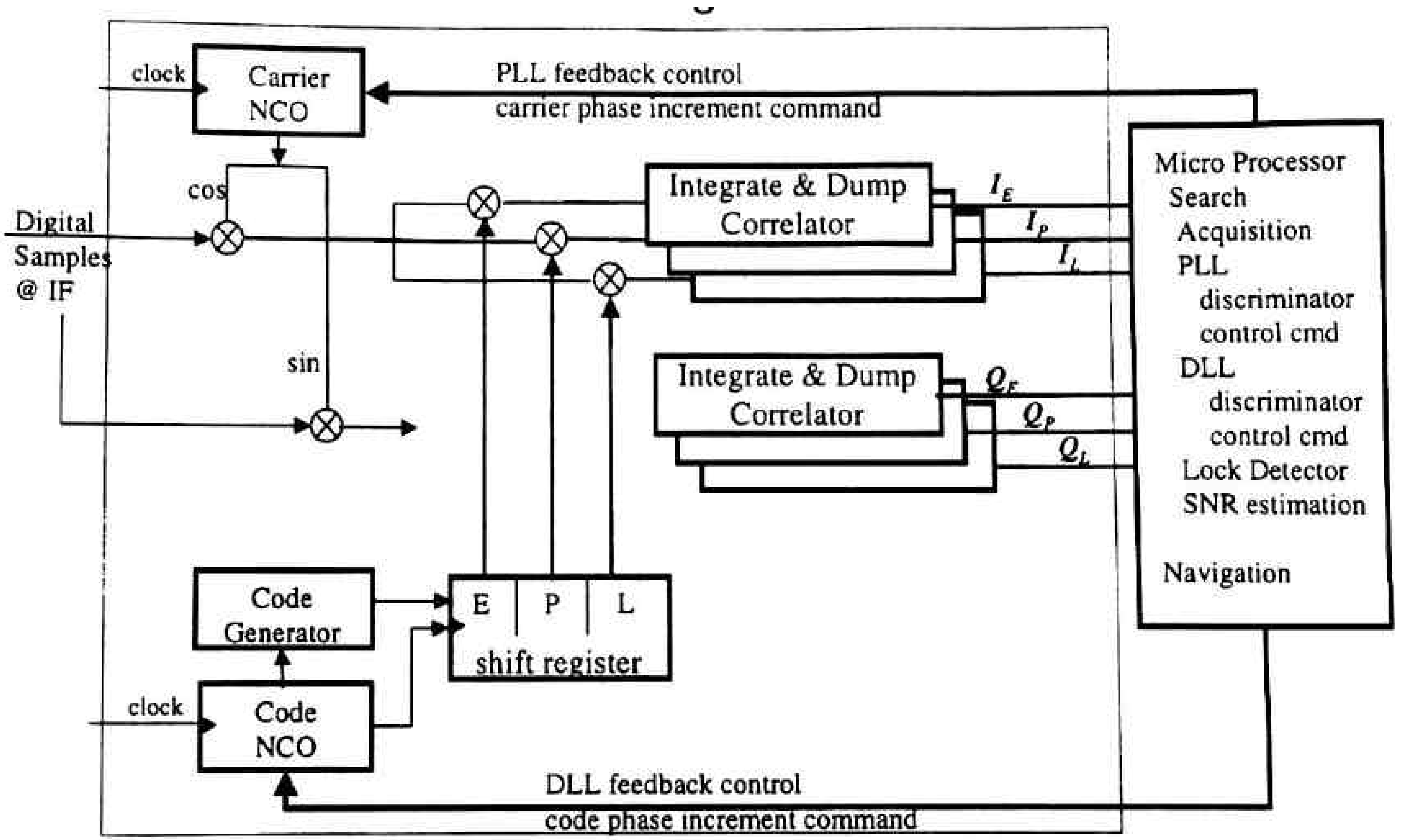
Trimble GPS Patch Antenna

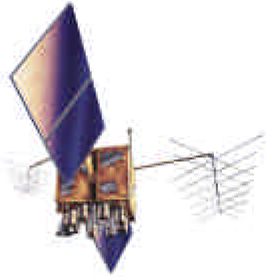
- Typical GPS Receivers
  - Trimble SK8/ACE GPS receiver ($90)
  - Garmin GPS35 ($160)
  - DeLorme Earthmate ($85)
  - Have seen some as cheap as $50
- Interface
  - Single or dual serial port
  - Protocols: NMEA-0183, TSIP, TAIP, Garmin, Rockwell Binary, others…
- Power
  - Typical requirements: 5V @ 200mA
- Where to buy
  - Electronics outlets (Fry's, GoodGuys, etc)
  - Electronic Surplus (Halted, All electronics, etc)
  - Internet (where else!?!)

GPS RECEIVER RF FRONT END



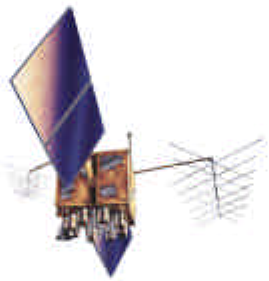
RECEIVER CORRELATOR & PROCESSOR





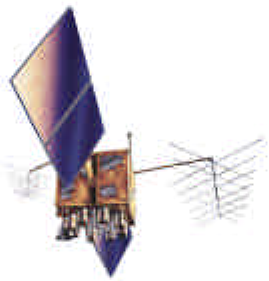
NMEA-0183

- National Marine Electronics Association 0183 (NMEA-0183)
  - (Inter)National standard for navigation data exchange among marine electronics (GPS, LORAN, wind/water speed sensors, autopilot, etc)
  - Adopted by GPS community as defacto standard for simple output-only Position-Velocity-Time reporting
  - Available on nearly every commercial GPS with a serial port
  - Uses standard serial port (RS-232C) at 4800,8,N,1 default
  - Output-only ASCII-only string-based protocol
  - NMEA strings:
    - $GPGGA – GPS fix data message (lat, lon, time, #SVs, etc)
    - $GPGGL – Geographic position (lat, lon, time)
    - $GPGSA – GPS DOP and active satellites (SVs, P,H,VDOP)
    - $GPGSV – GPS satellites in view (SV elevation/azimuth, SNR, etc)
    - $GPVTG – GPS velocity and heading
    - $GPZDA – Time & Date message
  - NMEA strings are followed by a precisely defined number of fields which carry the data. Data recovery can be as easy as using sprintf(…).



TRIMBLE TSIP/TAIP

- Trimble Standard Interface Protocol (TSIP)
  - Binary Packet Communications Protocol over RS-232C (9600,8,O,1 default)
  - Available on nearly all Trimble GPS products
  - Best for complete embedded control of GPS receiver
  - Allows reading and control of:
    - All processed GPS data (position, velocity, time)
    - All raw GPS data (pseudoranges, carrier phase, PDOP, TDOP, signal quality, SVs used, GPS system messages)
    - GPS receiver mode & parameters (serial port protocols, DGPS mode, SV selection mode, and more)
    - GPS hardware control (oscillator offset, mixer/integrator control, test modes, fast-acquisition modes, and more)
- Trimble ASCII Interface Protocol (TAIP)
  - Provides basic subset of TSIP commands in ASCII-only format
  - Great for low-overhead use of GPS receiver in projects with limited processor speed or RAM
  - Easy to learn



GPS RESOURSES

- Trimble Embedded Receivers
  - Spec Sheet: http://www.trimble.com/products/catalog/oem/lassen2.htm
  - Full manual: ftp://ftp.trimble.com/pub/sct/embedded/pubs/lassensk2man.pdf
    - Includes excellent NMEA, TSIP, and TAIP reference
- Garmin Embedded Receivers
  - GPS35 Full manual: http://www.garmin.com/manuals/spec35.pdf
- Stanford GPS courses
  - AA272C – GPS Theory and Operation
  - AA272D – Integrated sensor navigation (GPS, INS, etc)
- GPS links
  - General Info: http://www.gpsy.com/gpsinfo/