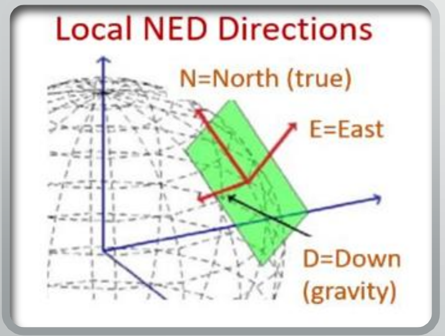
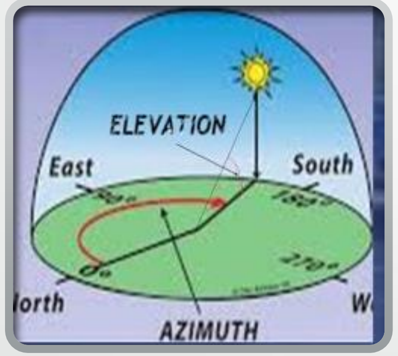
GPS6D TECHNOLOGY OVERVIEW

GPS6D is a next generation technology, extending GPS position and time by sensing the attitude of the antenna (i.e. 6-DOF orientation) through measuring the configuration of the GPS satellite constellation.

MULTIPATH SENSOR

Detects directions of interference with GPS signal, indicates line of obstruction by nearby physical features



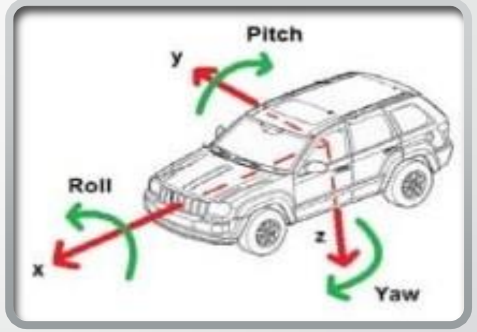


ORIENTATION SENSOR

Determines the 3 navigation directions (NED)

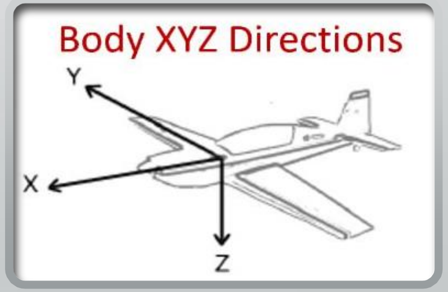
ALIGNMENT SENSOR

Measures the of arrival at which GPS signals are strongest



INCLINOMETER SENSOR

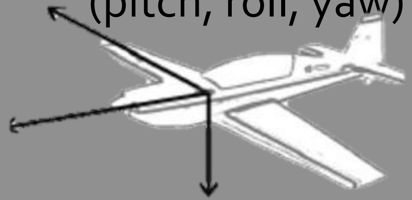
Provides 3 body angles relative to local NED



GPS6D Benefits

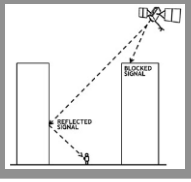
Body Orientation Data

Extends GPS. providing an independent source of geographical orientation (pitch, roll, yaw)



Miniaturization

Strong candidate for miniaturization, notably smaller footprint than systems requiring separated antennas



GPS Signal Identification

Provides a foundation for identifying fake GPS signals (anti-GPS spoofing) and physical signal obstructions

Reliable Redundancy

Additional standalone redundancy into PNT autonomous systems

Systems Integration

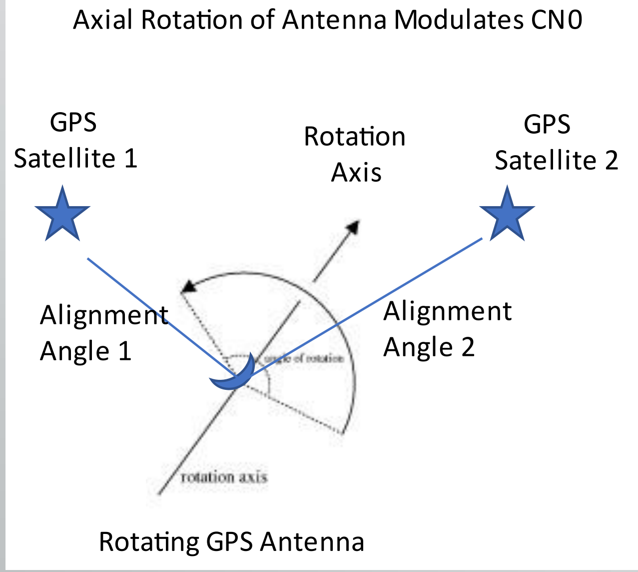
Platform for potential integration with MEMS and electrically small antennas

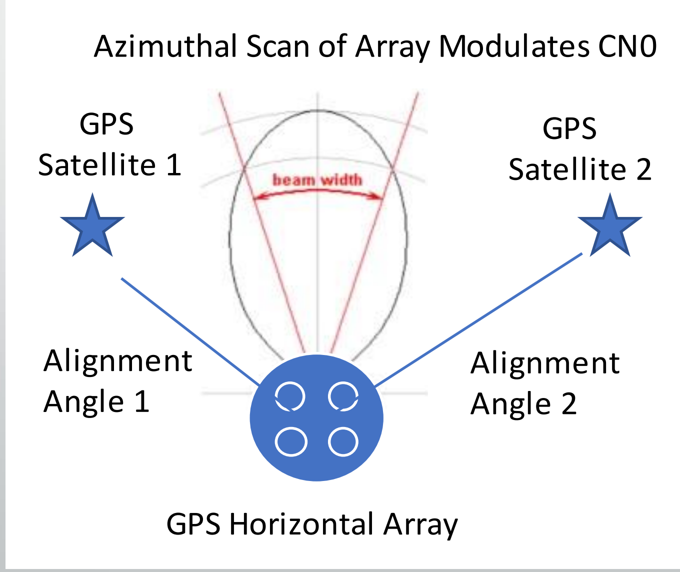
Low Cost Next Generation Technology

Builds on existing GPS infrastructure, allowing streamlined integration path with current systems

GPS6D MILESTONES

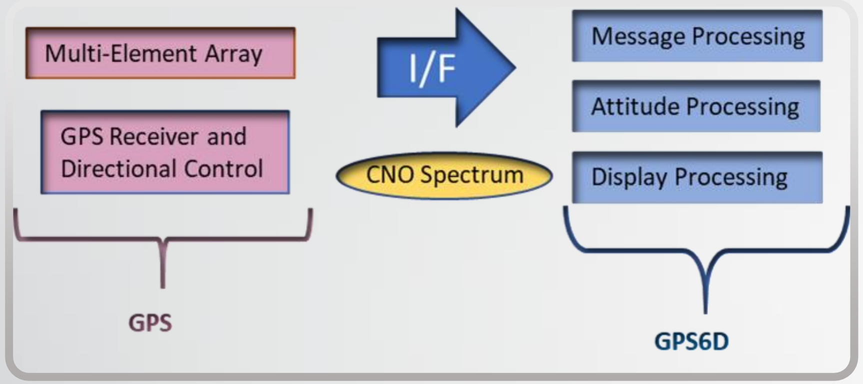
- ✓ US Patent Published: November 2011
  - US Patent: US 2011/0285590 A1
  - Dr. Robert Wellington
- ✓ Prototype 1- Data taken from precision antennas: 2015
- ✓ Prototype 2- Miniaturization, software testing: 2018

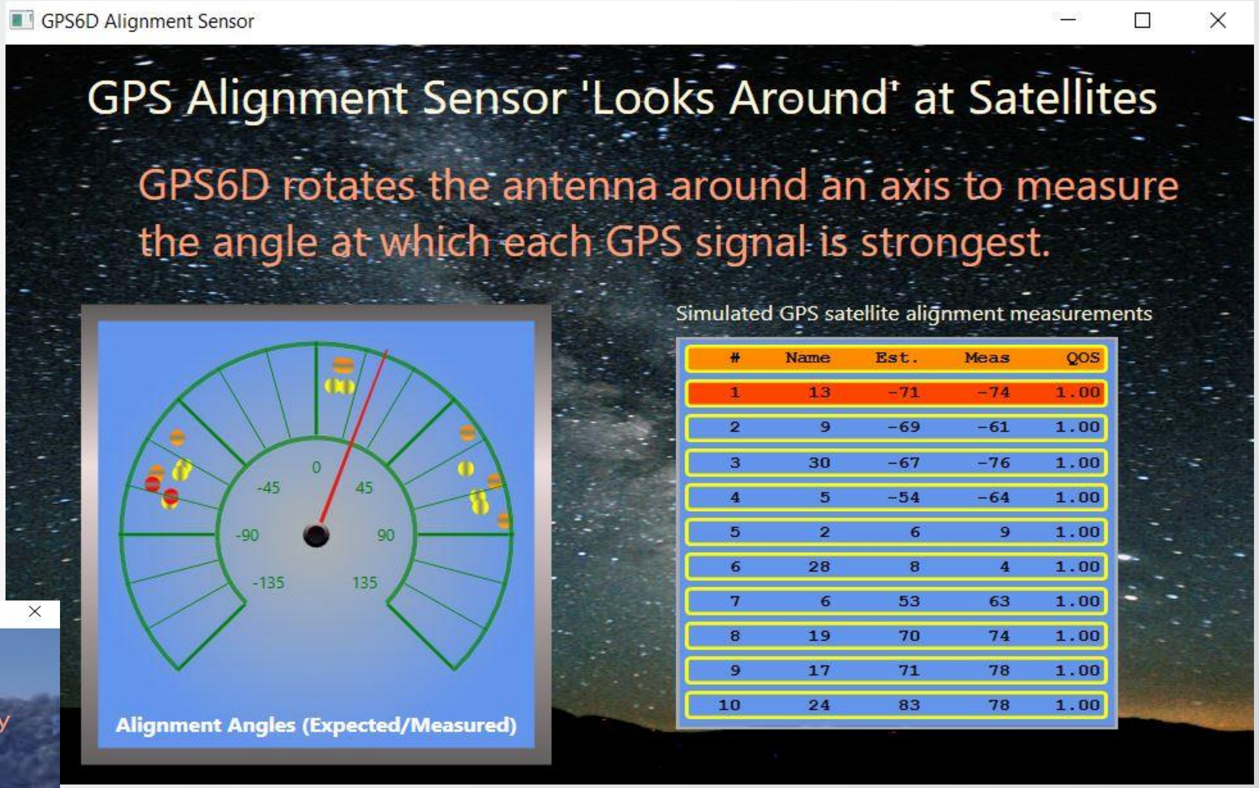




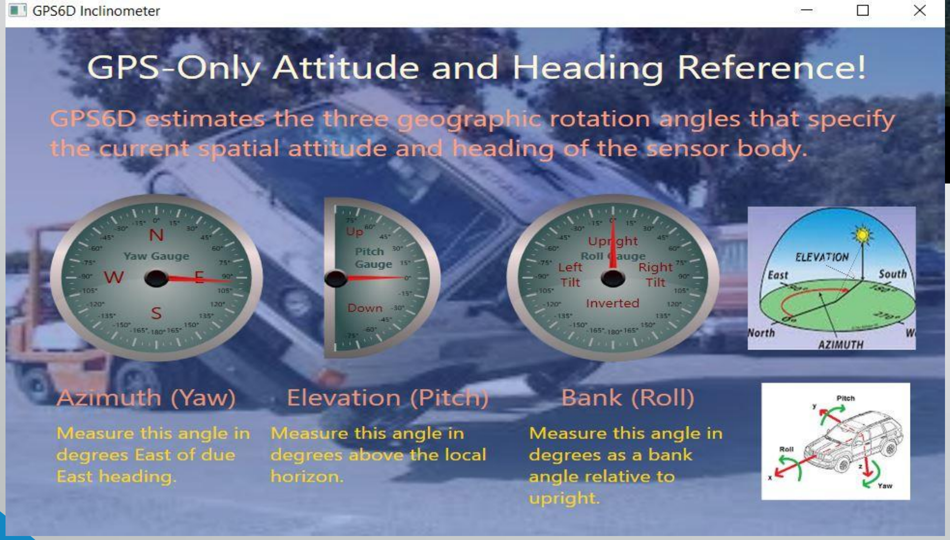
GPS6D DASHBOARD

GPS6D is read



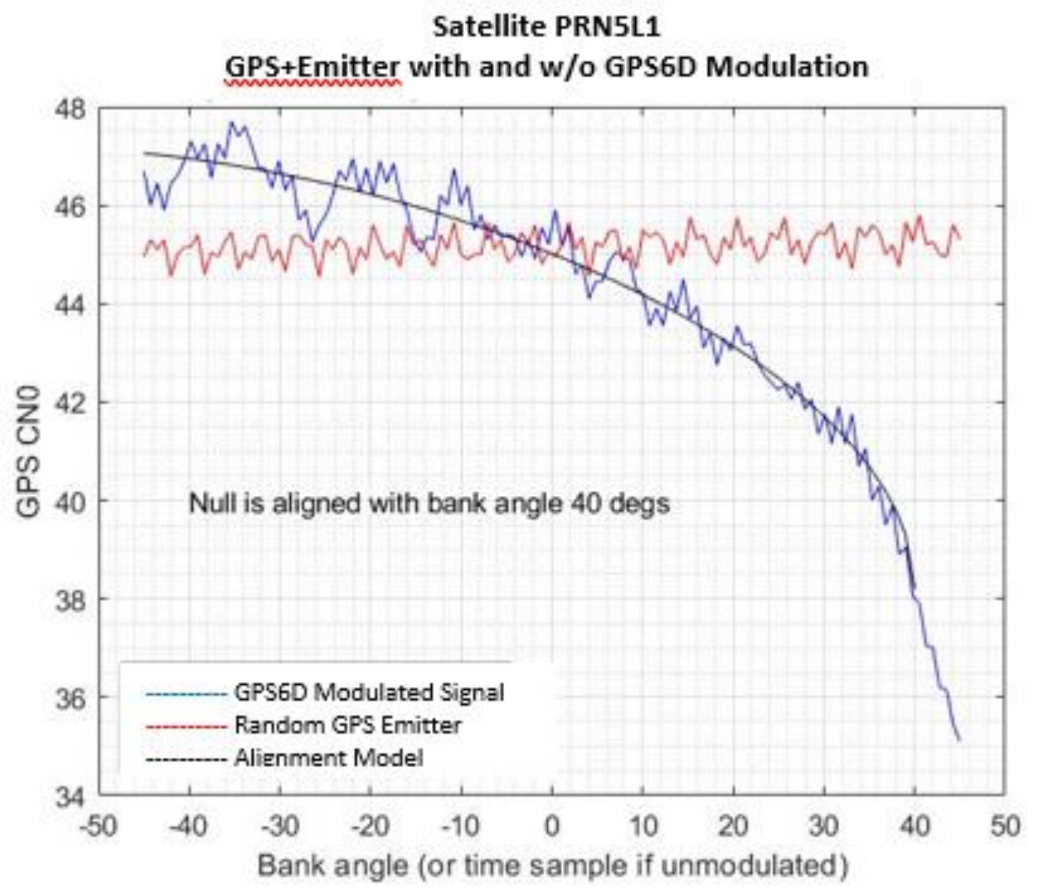


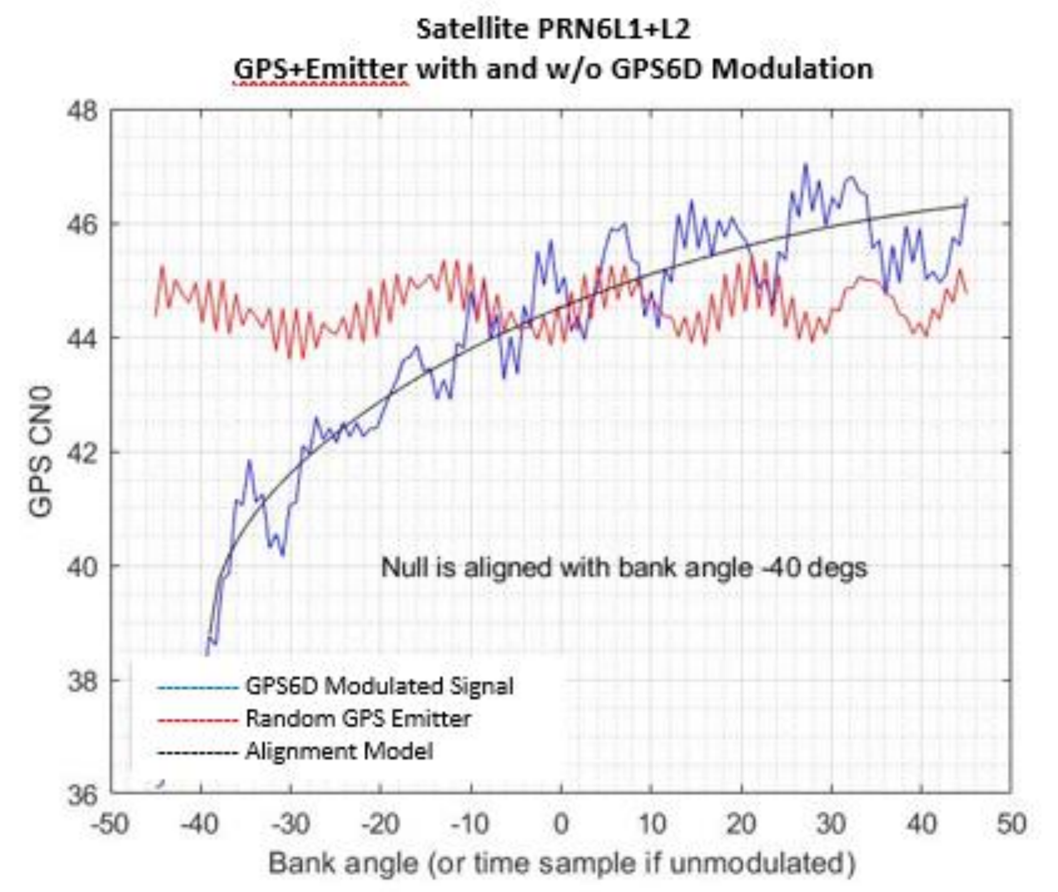
#	Name	Est.	Meas	QOS
1	13	-71	-74	1.00
2	9	-69	-61	1.00
3	30	-67	-76	1.00
4	5	-54	-64	1.00
5	2	6	9	1.00
6	28	8	4	1.00
7	6	53	63	1.00
8	19	70	74	1.00
9	17	71	78	1.00
10	24	83	78	1.00



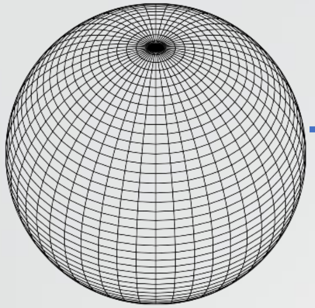
GPS6D Analysis

Alignment even in the presence of emitter signals





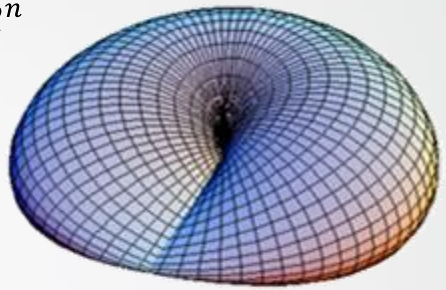
GPS6D MATHTASTIC CHART



Alignment Model: $G: H \rightarrow R^n$ by $G(q) = \vec{\alpha} = (\alpha_1, \alpha_2, .., \alpha_n) \epsilon R^n$

$\pi: S^3 \rightarrow RP^3$ so that $G: H \approx S^3 \rightarrow RP^3 \rightarrow R^n$

$\pi_2: S^2 \rightarrow RP^2$



- $\vec{r}(1) = (L/(2\surd 2) * (1, 1, 0); \vec{r}(2) = (L/2\surd 2) * (-1, 1, 0);$
- $\vec{r}(3) = (L/(2\surd 2) * (-1, -1, 0); \vec{r}(4) = (L/(2\surd 2) * (1, -1, 0);$

- Complex signal arrives as a plane wave of the form S(t) = R(t)*exp(j*theta(t)); ignore polarization for R(t) and recognize that theta(t) is changing as the GPS frequency. Convenient to describe the arriving signal as having a pseudo-azimuth phi0 relative to X and a vertical polar angle theta0, so the vector direction in X, Y and Z is then:
  - $S0 = (sin(\theta 0) * cos(\varphi 0), sin(\theta 0) * sin(\varphi 0), cos(\theta 0))$
- Wave vector: $\vec{k} = (2\pi\ \lambda) * S0$. Projection of wavevector onto array vectors gives the relative phase delays at the corners of the square
  - $\vec{k} \cdot \vec{r}(1) = (\pi/\surd 2) * sin(\theta 0) * (cos(\varphi 0) + sin(\varphi 0))$
  - $\vec{k} \cdot \vec{r}(2) = (\pi/\surd 2) * sin(\theta 0) * (-cos(\varphi 0) + sin(\varphi 0))$
  - $\vec{k} \cdot \vec{r}(3) = (\pi/\surd 2) * sin(\theta 0) * (-cos(\varphi 0) - sin(\varphi 0))$
  - $\vec{k} \cdot \vec{r}(4) = (\pi/\surd 2) * sin(\theta 0) * (cos(\varphi 0) - sin(\varphi 0))$
- Coherently sum the complex signals S(i), i=1…4, remove the relative phase shifts to get a matching phase for all 4 elements. The phase exactly matches in the direction of the satellite $S0$. Use the steering vector:
  - $\vec{V}(\vec{k}) = [\ exp(-j\vec{k} \cdot \vec{r}(1)), exp(-j\vec{k} \cdot \vec{r}(2)), exp(-j\vec{k} \cdot \vec{r}(3)), exp\ (-j\vec{k} \cdot \vec{r}(4))\ ]$

Add coherently to form the complex sum: $F = \sum \vec{V}(\vec{k})(i) S(i)\ i \approx 4 * S(t)$

INTERESTED IN FURTHERING THIS TECH?

- The company is currently seeking parties interested in further hardware development including antenna design, performance testing and commercialization of **GPS6D** technology
- All inquiries regarding this technology can be directed to:

Alissa Wellington, Chief Executive Officer
Six Degrees of Freedom GPS, LLC
Mobile: 952-201-8869
Office: 810-937-2727
Email: awellington@6dofgps.com