
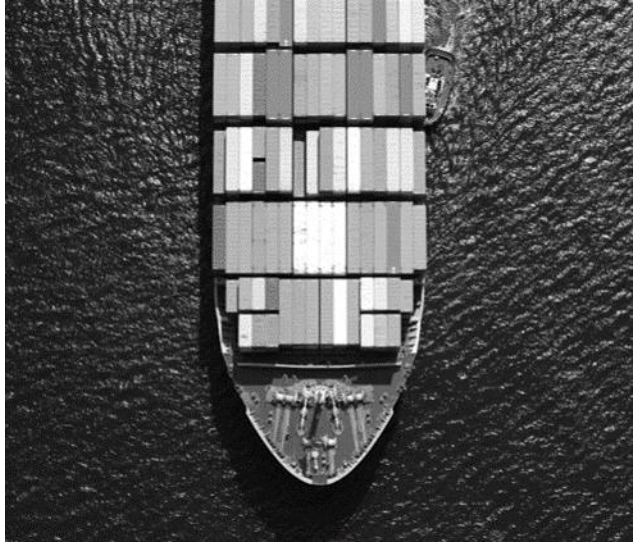

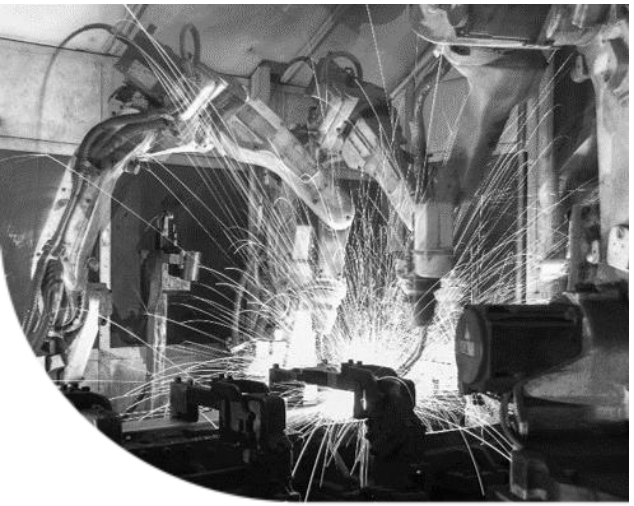

PTM 2 28 2018

HONEYWELL HG1120, HG4930 IMU & GNSS TRAINING

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Honeywell is building a smarter, safer,
and more sustainable world

THAT'S THE POWER OF **CONNECTED**
THAT'S THE POWER OF **HONEYWELL**

Connected Aircraft • Connected Automobile • Connected Home • Connected Building
Connected Plant • Connected Supply Chain • Connected Worker

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THE NEW HONEYWELL BUSINESS UNIT IS INTRODUCING IMUS TO THE MARKET

through our dedicated sales and support functions we listen to our customers and expand our portfolio
to support your future needs

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Inertial Measurement Units (IMUs) MEASURE LATERAL MOTION AND ROTATION IN **6 DEGREE'S OF FREEDOM** **9 Degrees with Magnetometers**

3 CORE MANUFACTURING TECHNOLOGIES:

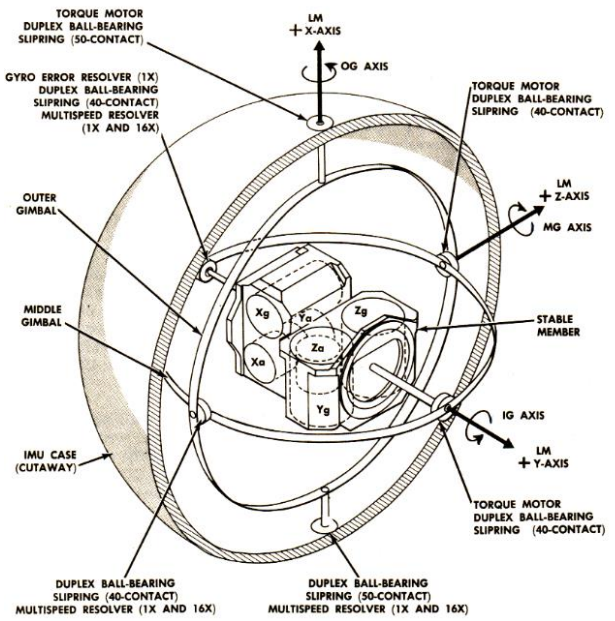
MEMS (Micro Electro Mechanical Systems)

RLG (Ring Laser Gyro)

FOG (Fibre Optic Gyro)

Each with Pro's / Con's- ex. Cost, Weight, Size, Ruggedness and possible Export Controls.

Since Honeywell's improvements, MEMS technology is now used in many traditionally FOG/RLG applications.



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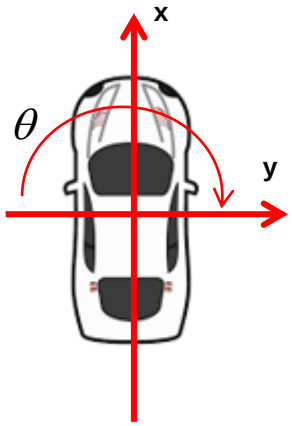
INS Fundamentals

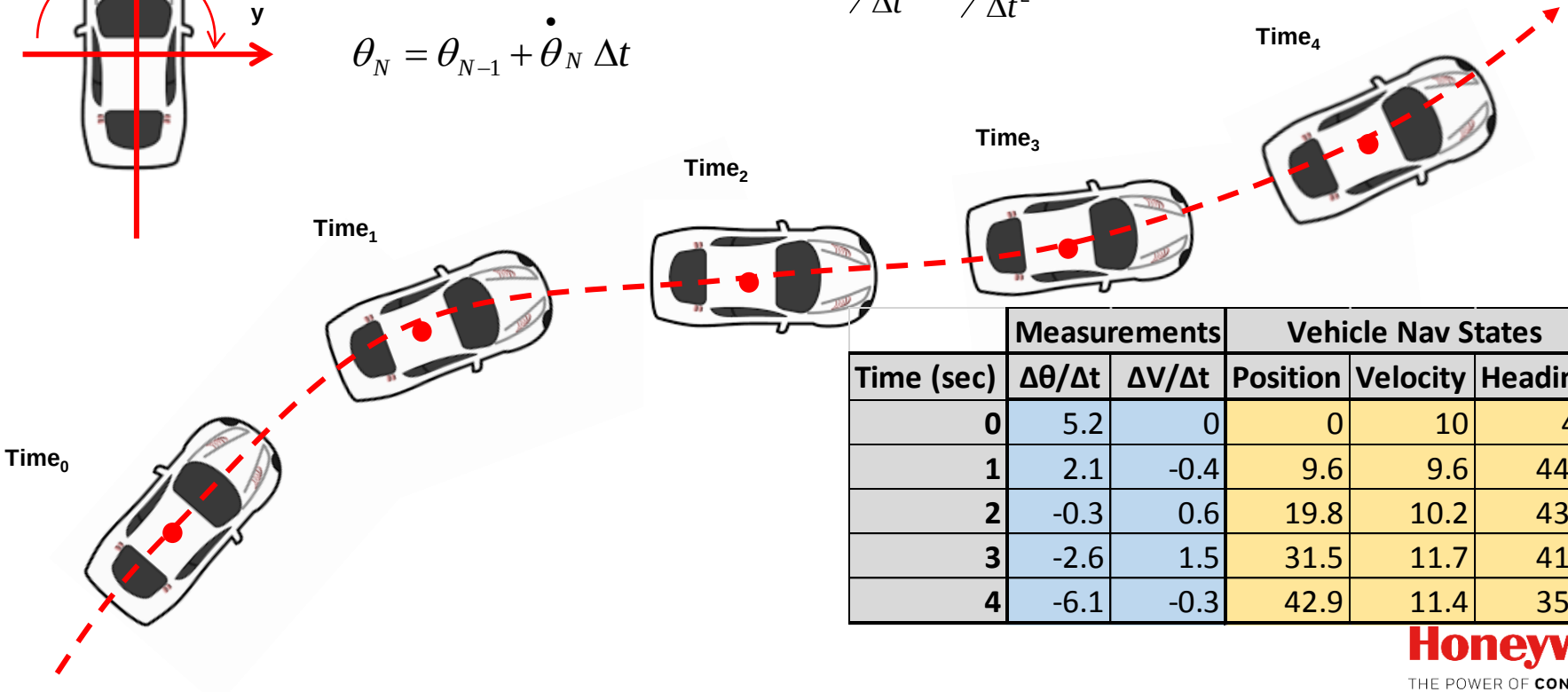
- **An IMU's primary purpose is to give rotational and translational measurements in order to determine how position and attitude (orientation) changes from one measurement to the next.**



$$P_N = P_{N-1} + \dot{P}_N \, \Delta t \quad Where, \dot{P} = \Delta P / \Delta t$$

$$\dot{P}_N = \dot{P}_{N-1} + \ddot{P}_N \, \Delta t \quad Where, \ddot{P} = \Delta \dot{P} / \Delta t = \Delta P / \Delta t^2$$

$$\theta_N = \theta_{N-1} + \dot{\theta}_N \, \Delta t$$



	Measurements		Vehicle Nav States		
Time (sec)	Δθ/Δt	ΔV/Δt	Position	Velocity	Heading
0	5.2	0	0	10	42
1	2.1	-0.4	9.6	9.6	44.1
2	-0.3	0.6	19.8	10.2	43.8
3	-2.6	1.5	31.5	11.7	41.2
4	-6.1	-0.3	42.9	11.4	35.1

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IMU Error Sources

- **Like any electro or mechanical device, IMU's are prone to a wide assortment of error sources. Common error sources include:**
  - **Noise**
  - **Scale Factor**
  - **Gravitational**
  - **Random Walk**
  - **Bias**
  - **Temperature & Thermal Gradient**
  - **Non-Linearity**
- **The quality of the IMU is dependent upon how much error can be calibrated out of the device. In general, less error means better accuracy and is are more valuable.**

Honeywell's World Class Calibration & Design Minimizes Error Sources To Provide A High Value Solution In Each Price Class.

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Navigation – External Measurements

- **Since we know IMU errors drift over time (regardless of quality), a navigation system can't rely solely on IMU information over long periods of time. It must rely on external measurements to correct for IMU errors.**

- **The most common external measurement for navigation is a Global Navigation Satellite System (GNSS), or GPS. However there are other measurements available to navigators including:**
  - **Radar**
  - **Sonar**
  - **Vision**
  - **Lidar**
  - **Magnetometer**
  - **Odometer**
  - **Range Finders**
  - **Barometer**
  - **Star Trackers**
  - **Space Junk Trackers**
  - **Earth's Rotation Rate & Direction**
  - **Ground Doppler**
  - **Ground Stations**
  - **ZUPT / Zero Heading**
  - **Transfer Alignment**

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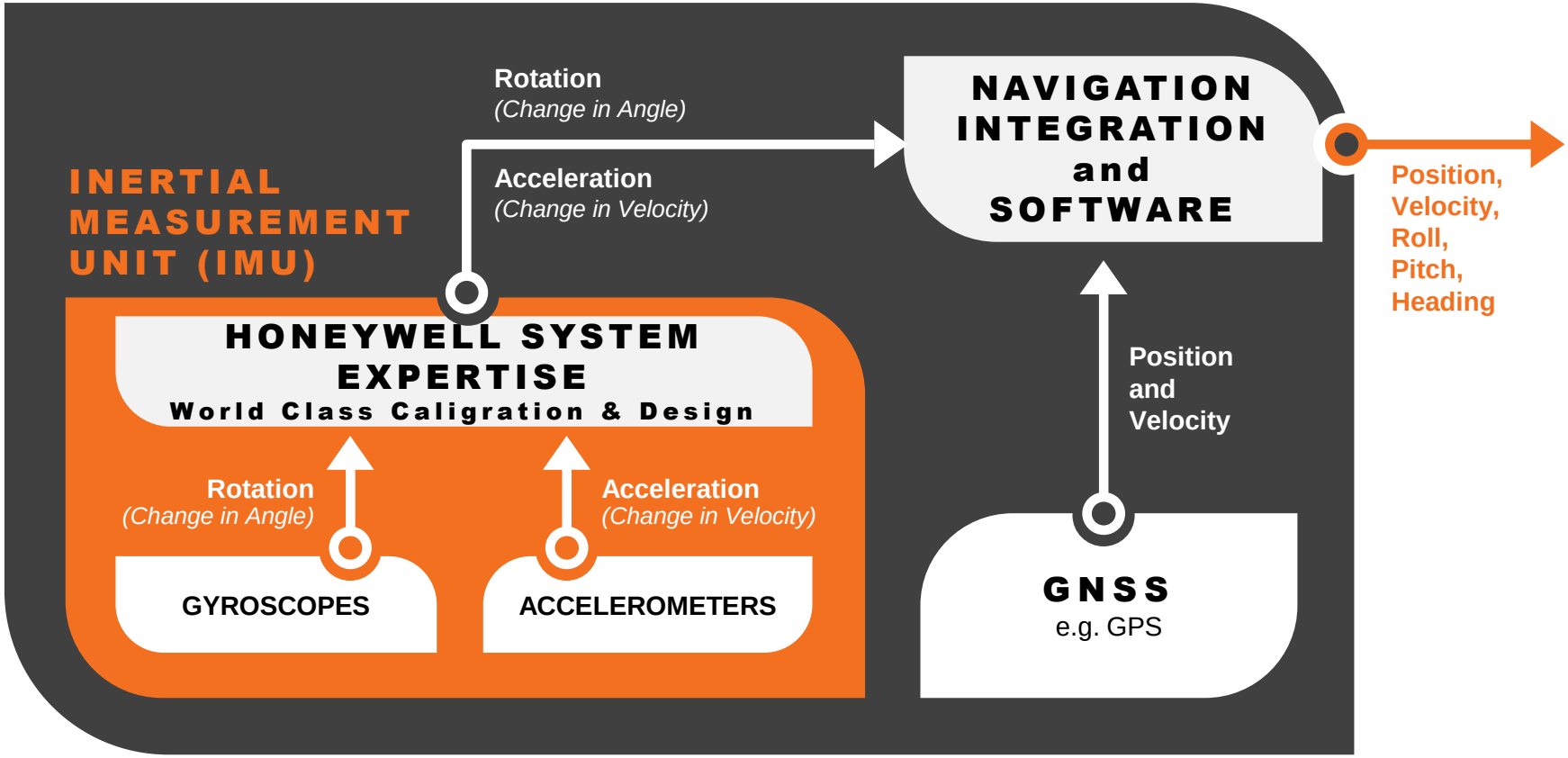
INERTIAL SENSOR
AND NAVIGATION PRIMER

GNSS-AIDED INERTIAL NAVIGATION SYSTEM (INS)



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WHY **GNSS + INERTIAL**

	GNSS	IMU	IMU + GNSS
			
DRIFT	NO	YES	NO
ACCURACY	<1CM	N/A	<1CM
WORKS ANYWHERE	NO	YES	YES
ORIENTATION	NO	YES	YES
UPDATE RATE	LOW	HIGH	YES
SERVICE ISSUES	YES	NO	NO
JAM/SPOOF PROOF	NO	YES	YES
6 DOF	NO	YES	YES

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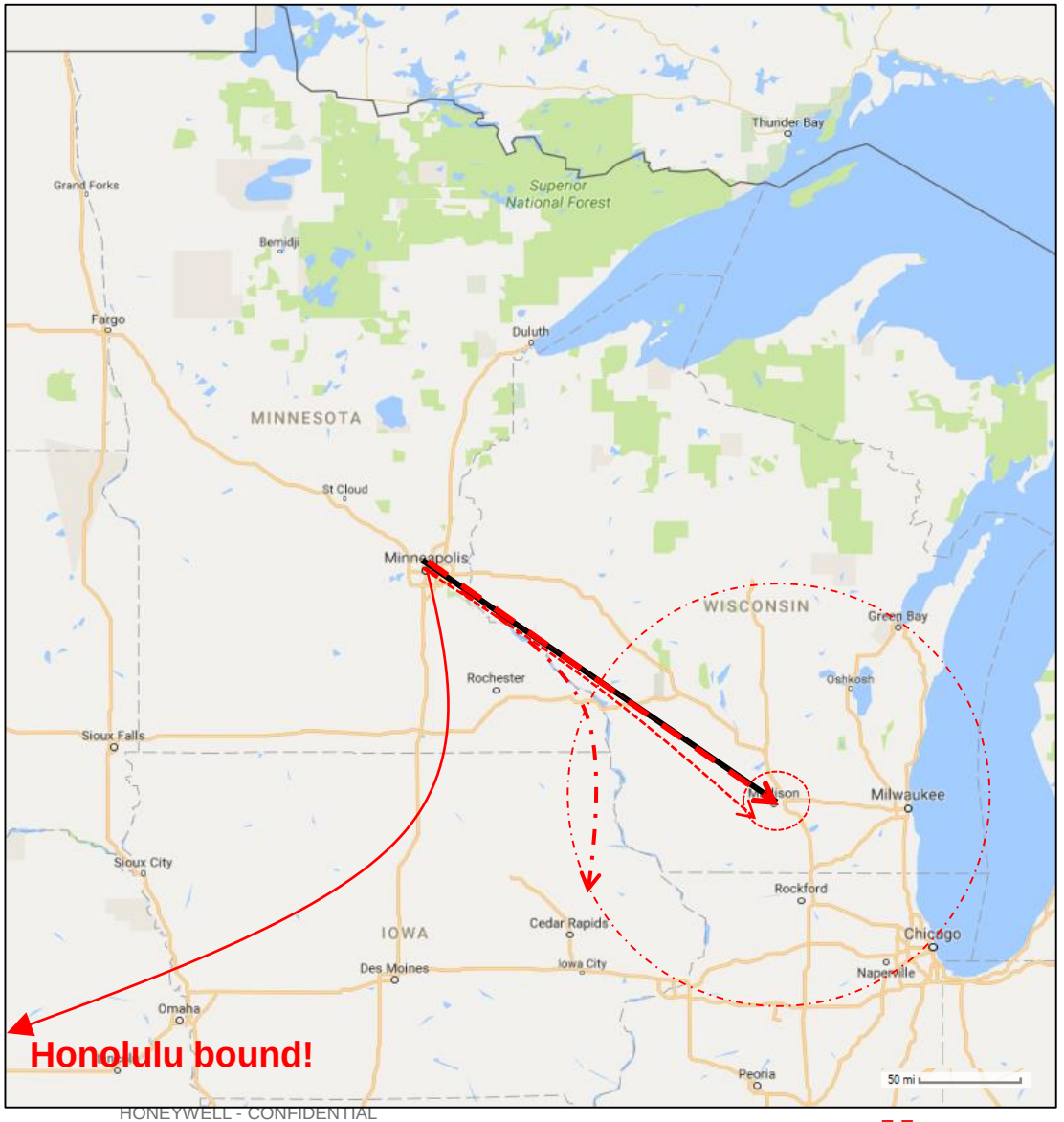
IMU Quality & How Errors Affect Navigation

- What happens if a un-calibrated system losses GPS? It has to rely solely on IMU measurements
- Situation: Flight from MSP to MSN (roughly a 1 hr flight)

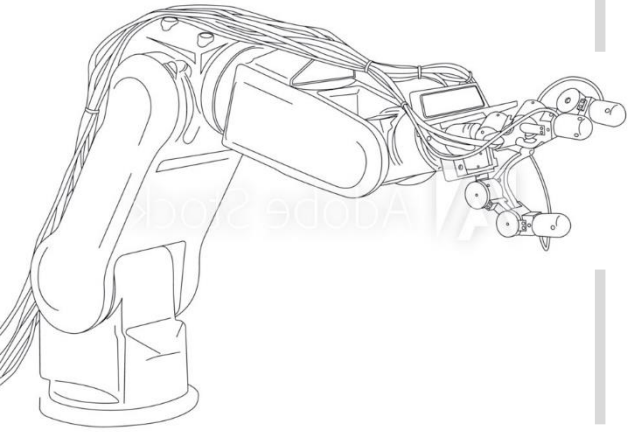
	Horizontal Position Error (m)			
IMU Grade	1s	10s	60s	1hr
Navigation	0.13 mm	12 mm	0.44 m	1.6 km
Tactical	1.5 mm	150 mm	5.3 m	19 km
Industrial	15 mm	1.5 m	53 m	190 km
Automotive	620 mm	60 m	2.2 km	7900 km



Truth
Navigation Grade
Tactical Grade
Industrial Grade
Automotive Grade

Position Uncertainty Proportional to the Quality of the IMU

WHAT TO USE?



IMUs

if you need to know

Platform Acceleration & Rotation

GNSS-AIDED INS

if you need to know

Platform Position, Velocity, Roll, Pitch & True Heading

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HONEYWELL **HG1120 IMU**

HG1120 IMU STANDARD MODELS TYPICAL PERFORMANCE- STABLE ROOM TEMPERATURE

Distributor Ordering PN	Gyro Bias Repeatability (°/hr)	Gyro Bias In-run Stability1 (°/hr)	ARW (°/√hr)	Accel Bias Repeatability (mg)	AccelBias In-run Stability1 (mg)	VRM (fps/√hr)
HG1120CA50	260	10	0.3	5	0.03	0.20
HG1120BA50	520	24	0.4	10	0.05	0.25
HG1120AA50	780	48	0.5	15	0.08	0.30

HG1120 IMU KEY CHARACTERISTICS

Volume/Size	1.7 in3 (29 cm3) / 1.850” x 1.730 x 0.557”
Weight	54 grams Typical
Power Consumption	<0.4 Watts
Operating Temperature Range	-54°C to 85°C
Data Rate	Up to 300 Hz (Guidance) and 1800 Hz (Control)- user configurable
Built-In-Test Coverage	>75%
Gyroscope Operating Range	Up to 500 deg/sec in all axes
Accelerometer Operating Range	Up to 16g in all axes
Supply Voltages	+3.0 to +5.5 VDC

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HONEYWELL **HG4930 IMU**

HG4930 IMU KEY CHARACTERISTICS

Distributor Ordering PN	Gyro Bias Repeatability (°/hr)	Gyro Bias In-run Stability1 (°/hr)	ARW (°/√hr)	Accel Bias Repeatability (mg)	AccelBias In-run Stability1 (mg)	VRM (fps/√hr)
HG4930CA51	7	0.25	0.04	1.7	0.025	0.030
HG4930BA51	10	0.35	0.05	2.0	0.050	0.040
HG4930AA51	20	0.45	0.06	3.0	0.075	0.060

HG4930 IMU KEY CHARACTERISTICS

Volume	82 cm^3 (5in^3), (65 x 51 x 35.5 mm Envelope)
Weight	140 grams, 0.3 lbs
Power Consumption	<2 Watts
Operating Temperature Range	-54°C to 85°C (Varies by configuration)
Data Rate	100 Hz (Guidance) and 600 Hz (Control)- other rates available
Built-In-Test Coverage	>89%
Gyroscope Operating Range	+/- 350 degrees/sec)
Accelerometer Operating Range	+/- 20 g
Supply Voltages	+5V

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IMU Comparisons - Key Characteristics

KEY CHARACTERISTICS	HG4930	HG1120
Volume/ Size	82 cm^3 (5in^3), (65 x 51 x 35.5 mm)	1.7 in3 (29 cm3) / 1.850” x 1.730” x 0.557”
Weight	140 grams, 0.3 lbs	54 grams
Operating Temperature	-54 to +85°C	-54C to 85oC
Power Consumption	< 2 Watts (Standard Series) TBD (Stabilization Series)	< 0.4 Watts Typical
Supply Voltage	+5 VDC +/- 5%	+3.0 to +5.5 VDC
Gyroscope Range	+/- 350 degrees/second	+/- 500 degrees/sec
Accelerometer Range	+/- 20 g	+/- 16 g
Magnetometer Range	NA	Up to 16 gauss in all axes
Communication	RS-422 Asynchronous Protocol 1Mbits/sec	RS-422 Asynchronous, CAN, and SPI Protocols - 1Mbits/sec
Data Rates Navigation (Guidance)	100Hz (Navigation) Fully Compensated Incremental / Delta Outputs. Ready for Integration into Position/Attitude 1800 Hz Unfiltered Sensor Data Summed To 100Hz	100 or 300 Hz (Navigation) Fully Compensated Incremental / Delta Outputs. Ready for Integration into Position/Attitude 1800 Hz Unfiltered Sensor Data Summed To 100 Hz or 300 Hz
Data Rates Control	600Hz (Control) Stabilization Configurations Optimize Latency & Bandwidth **1800 Hz Filtered Angular And Linear Data Decimated For 600Hz**	600Hz or 1800Hz (Control) Stabilization Configurations Optimize Latency & Bandwidth 1800 Hz Filtered Angular And Linear Data Decimated For 600 or 1800Hz

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IMU Comparisons – Performance Over Temp

HG4930 IMU TYPICAL PERFORMANCE OVER FULL TEMPERATURE RANGE							
Distributor Ordering Part Number[1]	Performance Class	Gyro Bias Repeatability (°/hr 1σ)	Gyro Bias In-run Stability	Gyro ARW (°/√hr)	Accel Bias Repeatability (mg 1σ)	Accel Bias In-run Stability (mg 1σ)	Accel VRW (m/s/√hr)
HG4930-CA51	C	7	0.25	0.04	1.7	0.025	0.03
HG4930-BA51	B	10	0.35	0.05	2	0.05	0.04
HG4930-AA51	A	20	0.45	0.06	3	0.075	0.06

HG1120 IMU TYPICAL PERFORMANCE – STABLE ROOM TEMPERATURE							
Distributor Ordering Part Number[1]	Performance Class	Gyro Bias Repeatability (°/hr 1σ)	Gyro Bias In-run Stability[2]	Gyro ARW (°/√hr	Accel Bias Repeatability (mg 1σ)	Accel Bias In-run Stability (mg 1σ)	Accel VRW (m/s/√hr)
HG1120-CA50	C	260	10	0.3	5	0.03	0.04
HG1120-BA50	B	520	24	0.4	10	0.05	0.06
HG1120-AA50	A	780	48	0.6	15	0.08	0.10

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IMU Comparisons – Band Width & Data Rate

HG4930 IMU Typical Bandwidth and Data Rate Characteristics					
Distributor Ordering Part Number[1]	Device Class	Stabilization BW -90°/-3 dB (Hz)		Data Rates	Baud Rate
		Gyro	Accel	Control Stabilization	Navigation Guidance	
HG4930-CA51 HG4930-BA51 HG4930-AA51	Standard	70/180	70/180	600 Hz	100 Hz	1 MBit

HG1120 IMU Typical Bandwidth and Data Rate Characteristics						
Device Class		BW -90°/-3 dB (Hz)		Data Rates		Baud Rate
		Gyro	Accel	Control Stabilization	Navigation Guidance	
Standard	50Hz	51/94	53/80	600Hz or 1800Hz	100 Hz or 300 Hz	1 MBit
	90Hz	92/211	91/176	600Hz or 1800Hz	100 Hz or 300 Hz	1 MBit
	No Filter	97/298	160/288	600Hz or 1800Hz	100 Hz or 300 Hz	1 MBit

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AUTONOMOUS OR MANNED APPLICATIONS

INDUSTRIES

- Academic
- Agriculture
- Automotive
- Communication
- Construction
- Energy
- Inspection
- Mapping
- Marine
  - Surface & Subsea
- Mining
- Robotics
- Transportation
- Not to mention Aerospace and Defense

PLATFORMS

- Airplanes
- Cranes
- Helicopters
- Pipeline Pig
- Robots
- Remotely Operated Vehicles (ROVs)
- Sensors
  - Camera, IR, Lidar, Radar, …
- Trains
- Unmanned Arial Vehicles (UAVs)
- Unmanned Ground Vehicles (UGVs)
- Unmanned Underwater Vehicles (UUVs)

APPLICATIONS

CONTROL

- Motion Compensation
- On the Move Satellite Communications
- Sensor Stabilization
- Platform Control

NAVIGATION (Real-Time or Offline)

- Pipeline Inspection
- Platform Navigation
- Surveying

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APPENDIX

GNSS + INERTIAL TECH EXPLAINER

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GNSS TECHNOLOGY HAS **REVOLUTIONISED** HOW WE UNDERSTAND OUR LOCATION

***Comprising GPS, GLONASS, Galileo and Beidou and several Augmentation services**

ABSOLUTE POSITION ACCURACIES FROM 3M TO UNDER 1CM ARE NOW AVAILABLE.

**Fundamental flaws- ex. receiver's antenna is unable to get a clear view of the sky*

Honeywell has a distinguished legacy of aerospace navigation products across multiple platforms, operating in harsh environments around the globe.

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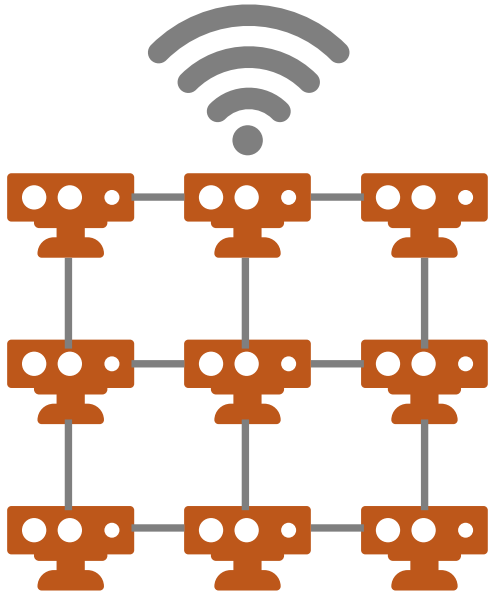
INS TECHNOLOGY
TYPICALLY COMPRISES AN IMU AND GNSS RECEIVER

TO BUILD A ROBUST NAVIGATION SOLUTION, MULTIPLE SENSORS ARE REQUIRED.

An accurate, robust position, attitude and time information are all available for your application by combining data from these technologies.

Honeywell has been providing blended navigation solutions to critical applications in the Aerospace market for decades



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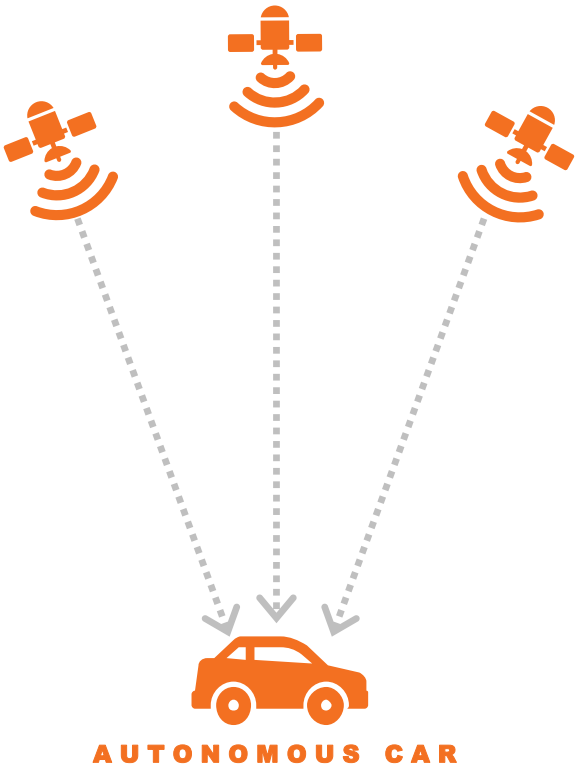
GNSS OVERVIEW

GNSS IS AN AMAZING TECHNOLOGY
that, for free, can pinpoint your position, anywhere in the world.

HOWEVER,
THERE ARE SOME
BIG DRAWBACKS
FOR CRITICAL
APPLICATIONS



BACK

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GNSS OVERVIEW & CHALLENGES

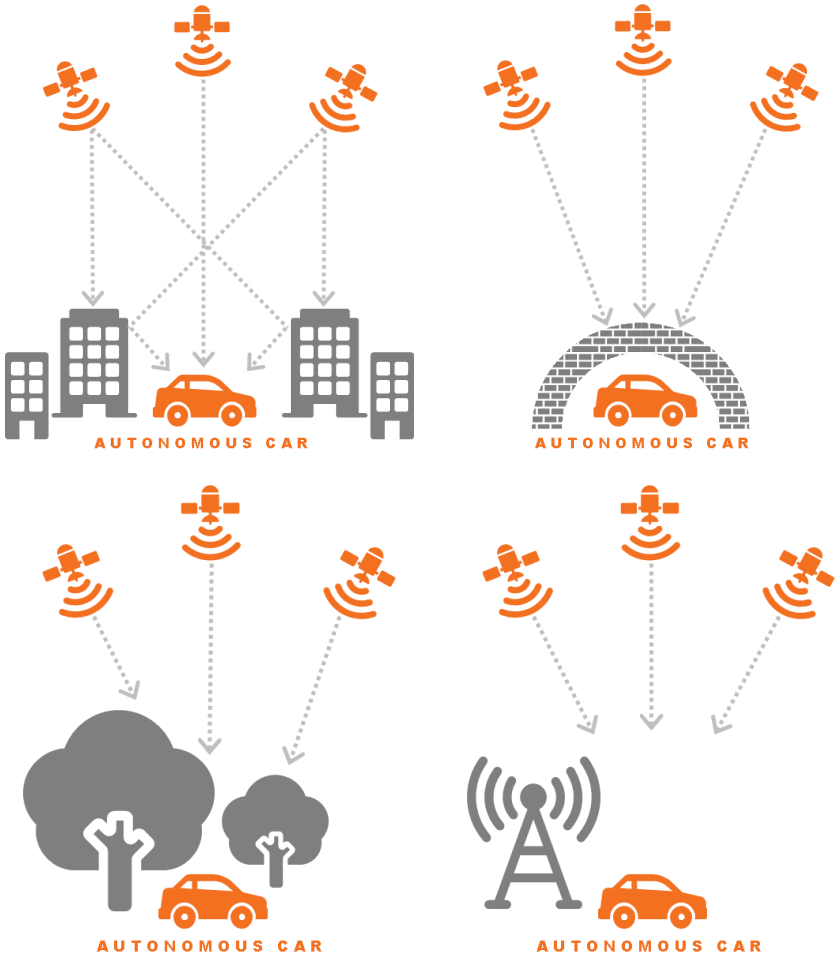
GNSS IS AN AMAZING TECHNOLOGY
that can pinpoint your position, anywhere in the world.

HOWEVER,
THERE ARE SOME
BIG DRAWBACKS
FOR CRITICAL
APPLICATIONS

Buildings
Tunnels
Natural Environment

All can block or interfere with the GNSS signal

GNSS signals are also easily Jammed and possibly Spoofed



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GNSS OVERVIEW & CHALLENGES

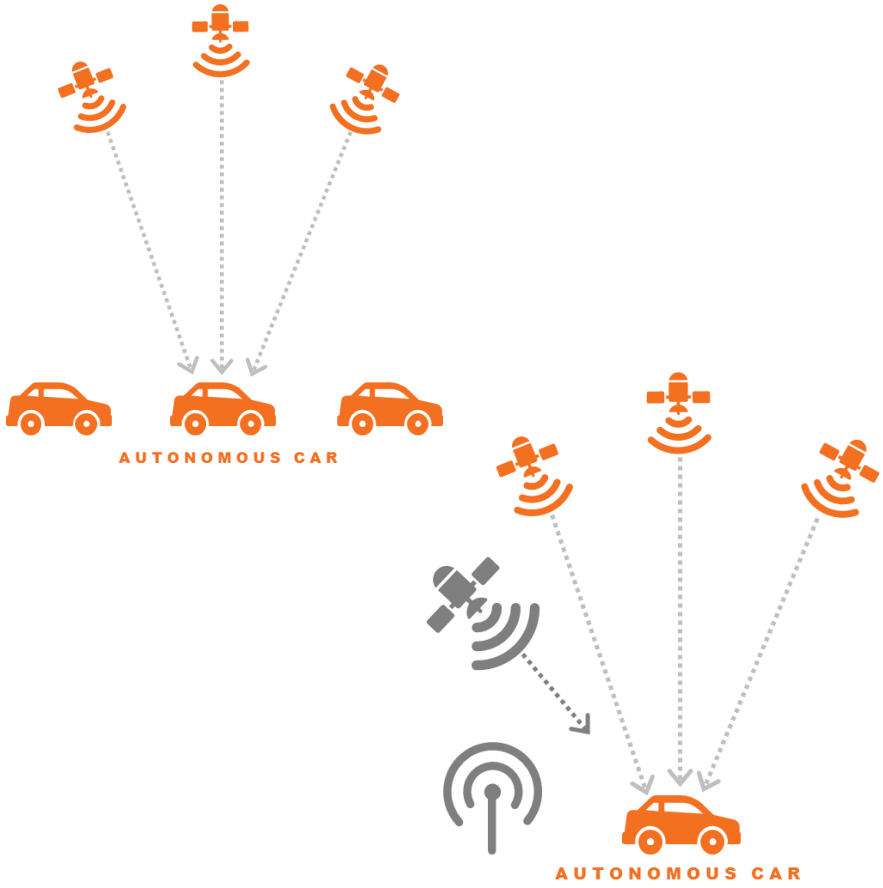
GNSS IS AN AMAZING TECHNOLOGY
that, for free, can pinpoint your position, anywhere in the world.

HOWEVER,
THERE ARE SOME
BIG DRAWBACKS
FOR CRITICAL
APPLICATIONS

The update Rate is too slow for accurately timestamping the position of a fast moving vehicle

Extra infrastructure/services required for cm level positioning

This can also be post-processed



Honeywell's IMUS Are A Critical Part Of Many Navigation Solutions.

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