Generation of an Open Source Catalog of Attitude and Orbit Control Subsystem (AOCS) Sensors and Actuators

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Presentation Outline

- Overview, motivation and uses of this study
- Description of the AOCS/GNC Sensor/Actuator Open Source Database (Catalog)
- Example Analyses
- Future Plans
- Conclusion

Overview

- The European Space Agency (ESA) together with NASA (NESC with Draper Laboratory support) and the have combined efforts in an effective collaboration to catalogue spacecraft GN&C hardware technologies.

- An initial focus has been on:
  - Gyroscopes/Inertial Sensors,
  - Star Trackers
  - Reaction Wheels
  - Sun Sensors

- Key Motivations:

  - Directly addresses the #1 GN&C State-of-the-Discipline issue as identified by the NASA Technical Fellow for GN&C.

  - Directly addresses the needs of ESA for the preparation of their AOCS hardware harmonisation dossier

Potential Uses of the Database

1. Create an easily accessible database of GNC components to aid GN&C and System Engineering decisions
   - (pre-phase A, phase A stage trades and help with requirement spec derivation in Phase B to ensure competition)
2. Determine if there are market segments not being well served by current offerings
   - What missions could be enabled by filling those gaps?
   - Are there any “low hanging fruit” for developments?
3. Provide objective gap analysis information for GNC component technology development investment priorities
   - Are any equipments only available from one geographical zone?
   - Is there risk of insufficient competition in any area?
   - Is a specific technical need not well addressed?
4. Help to determine the performance threshold of commercially available AOCS/ GNC components
   - Limits of performance/ technical trends (including interface support)

The Database

- Information collected from May to Sept 2014 via public sources only by both ESA and NASA/Draper.
- Initial Database contains information on:
  - Star Trackers (116 entries)
  - Gyros/IMUs (238 entries)
  - Sun Sensors (85 entries)
  - Magnetometers (37 entries)
  - Reaction Wheels (142 entries)

  (was manpower/ time limited)

Collecting the GN&C Component Data

- All data from **publically available sources** *No company proprietary or ITAR restricted information*
  - *Data sheets, websites and conference papers*
  - *Data sheets preferred source*
- Performance related information
  - *Various metrics (see next slide)*
- Heritage information, where available
  - *Much heritage data unavailable any more (pre-internet age)*
- Currently managed in a Google Spreadsheet, which allows concurrent editing (ESA/NASA/Draper)
- All data must have a reference
  - *Copy of the reference also stored*

Star Trackers

Supplier	Location (Drop Down: USA EU China Russia RoW)	Unit Name	Update Rate (Hz)	Field of view (Deg full cone)	Max Angular Rate (deg/sec)	Sun Exclusio (Deg half
Ball Aerospace	USA	CT-631	5	20.0		
Ball Aerospace	USA	CT-632		20.0 deg		
Ball Aerospace	USA	CT-633	5	20.0 deg		
Ball Aerospace	USA	FSC-701	30	22.0 deg		
Ball Aerospace	USA	HAST (High Accuracy Star Tracker)		8.8 deg		
Goodrich	USA	HD1003 Narrow FOV				

Suppliers | Star Tracker | Gyros | Magnetometers | Accels | Wheels | Sun Sensors | Lists

Open Source GN&C Component Data Collected

Gyroscopes

- Manufacturer
- Country of origin
- Model number
- Bias Stability (deg/hr)
- Angle Random Walk (ARW)
- Scale factor stability (ppm)
- Measurement Range
- Total Mass
- Number of axes measured
- Power consumption
- Measurement update rate
- Accelerometers (Y/N)?
- Interface
- Type (FOG/MEMS/etc)
- Configuration
- Notes on flight heritage and/or intended use

Star Trackers

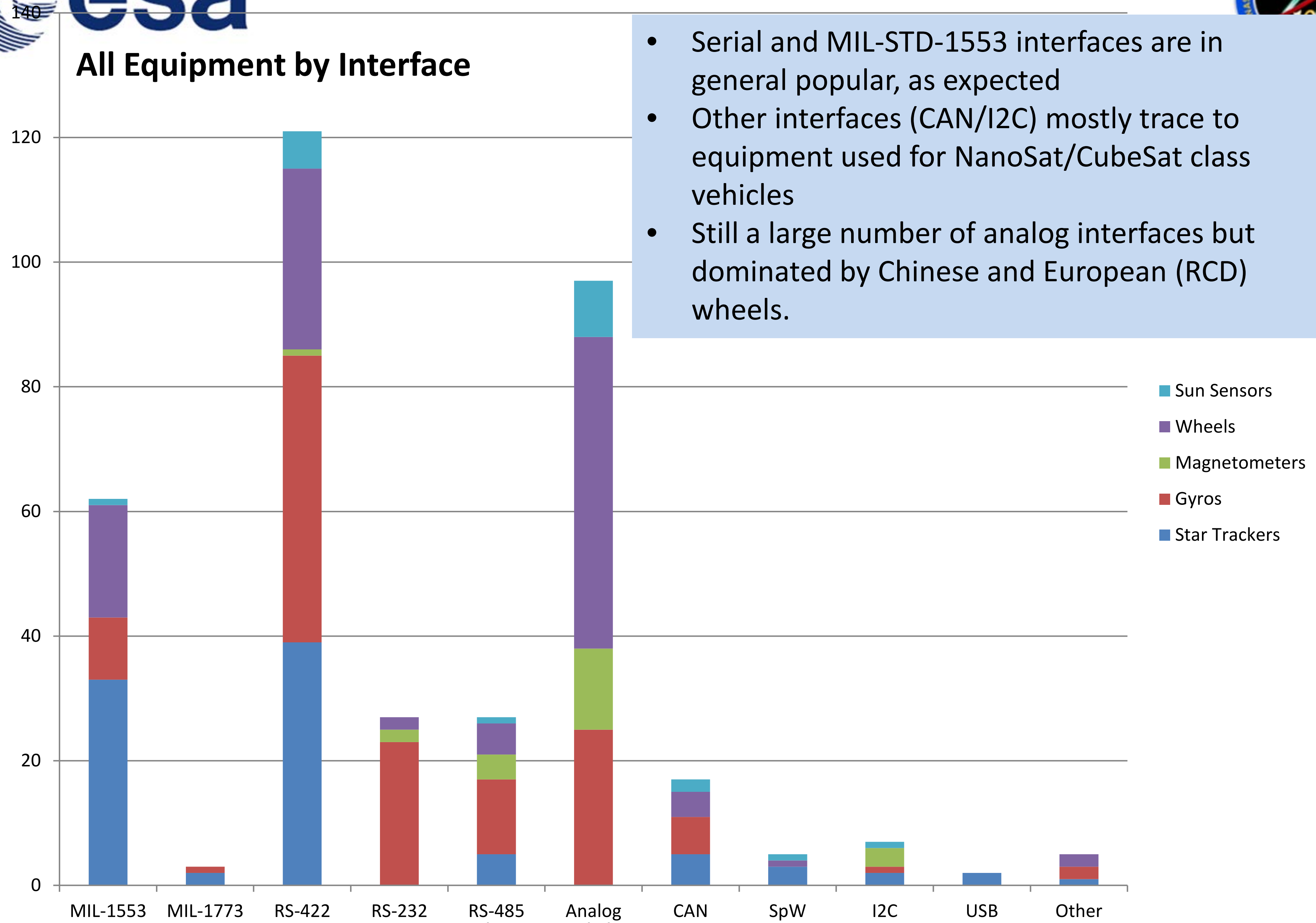
- Manufacturer
- Country of Origin
- Model Number
- Detector Type (CCD/CMOS)
- X/Y FOV
- NEA
- Total mass
- Nominal Power consumption
- Update Rate
- Functionality with moon in FOV
- Configuration
- Interface
- Notes on flight heritage and/or intended use

Sun Sensors

- Manufacturer
- Country of origin
- Model Number
- FOV
- Accuracy
- Axes measured
- Mass
- Power consumption
- Interface
- Sensor Type
- Notes on flight heritage and/or intended use

Example Observations on Component Interfaces

Interfaces Supported

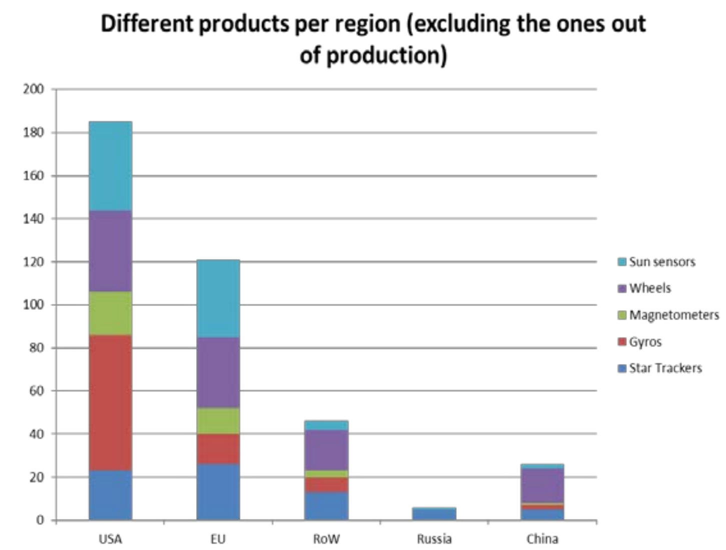


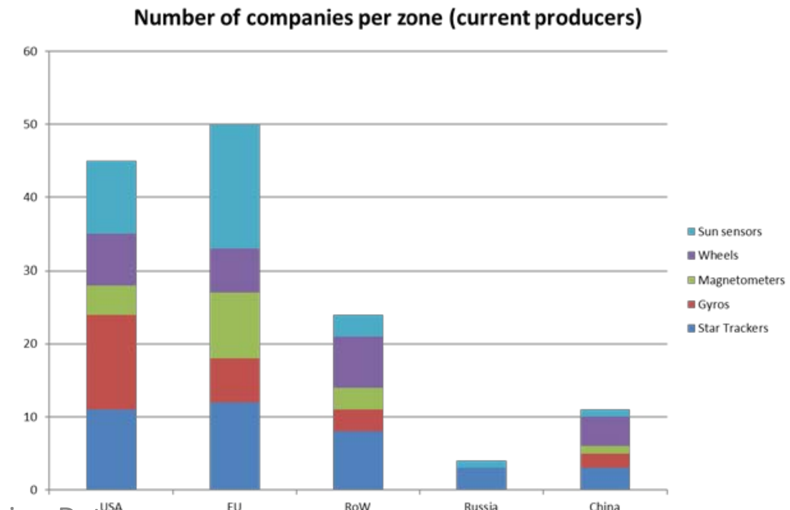
- Serial and MIL-STD-1553 interfaces are in general popular, as expected
- Other interfaces (CAN/I2C) mostly trace to equipment used for NanoSat/CubeSat class vehicles
- Still a large number of analog interfaces but dominated by Chinese and European (RCD) wheels.

Example Observations on Regional Distributions

Regional Observations

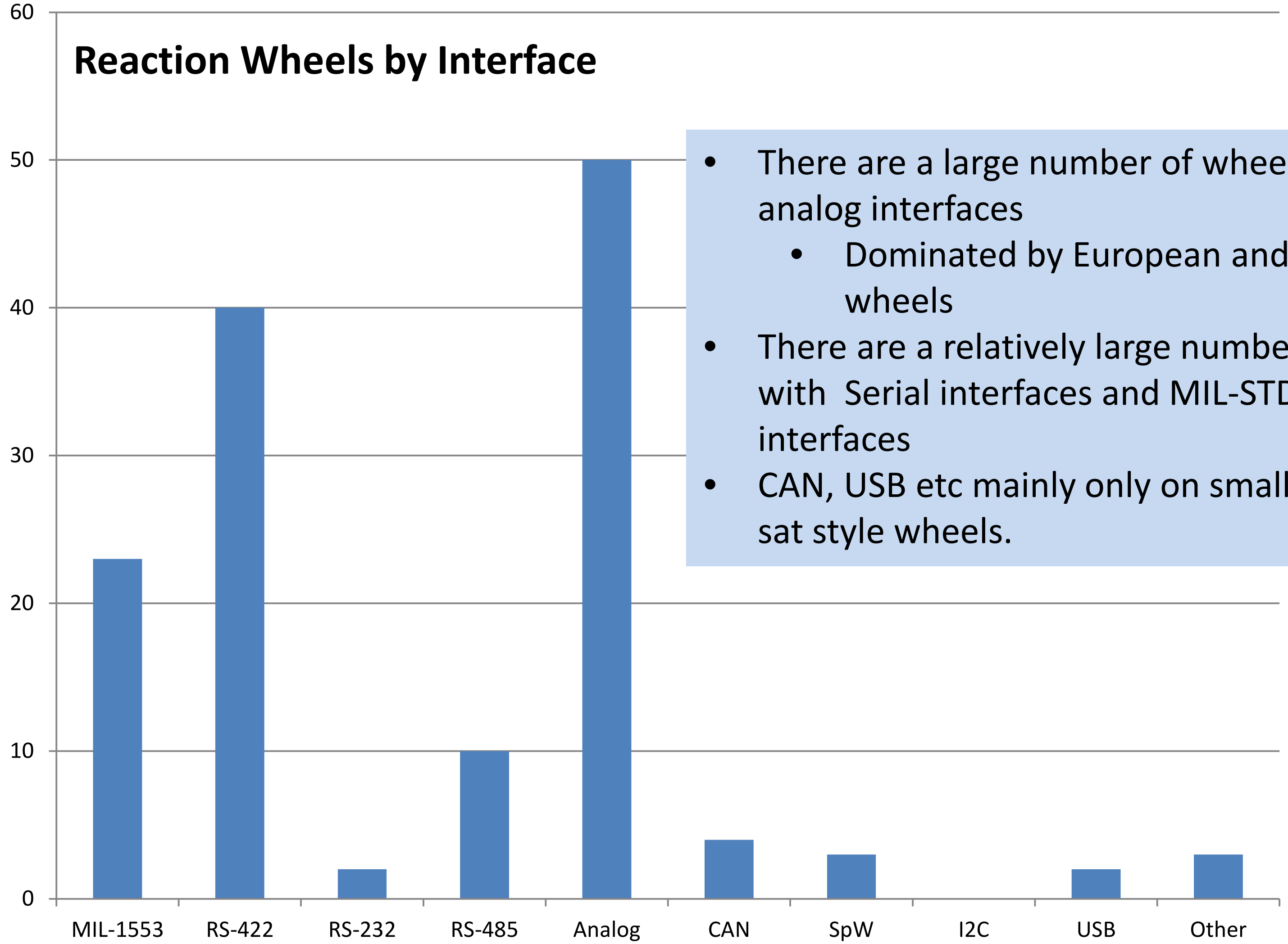
- USA produces the most variety of GN&C avionics hardware overall
- USA dominates the gyro market by products and companies
- EU has the greatest number of companies/institutions producing GN&C hardware
- USA has a smaller number of GN&C hardware producers compared to EU (and the number is possibly diminishing)
- Information on Russia/ old Eastern block countries is very likely highly incomplete





Example Analysis on Equipments

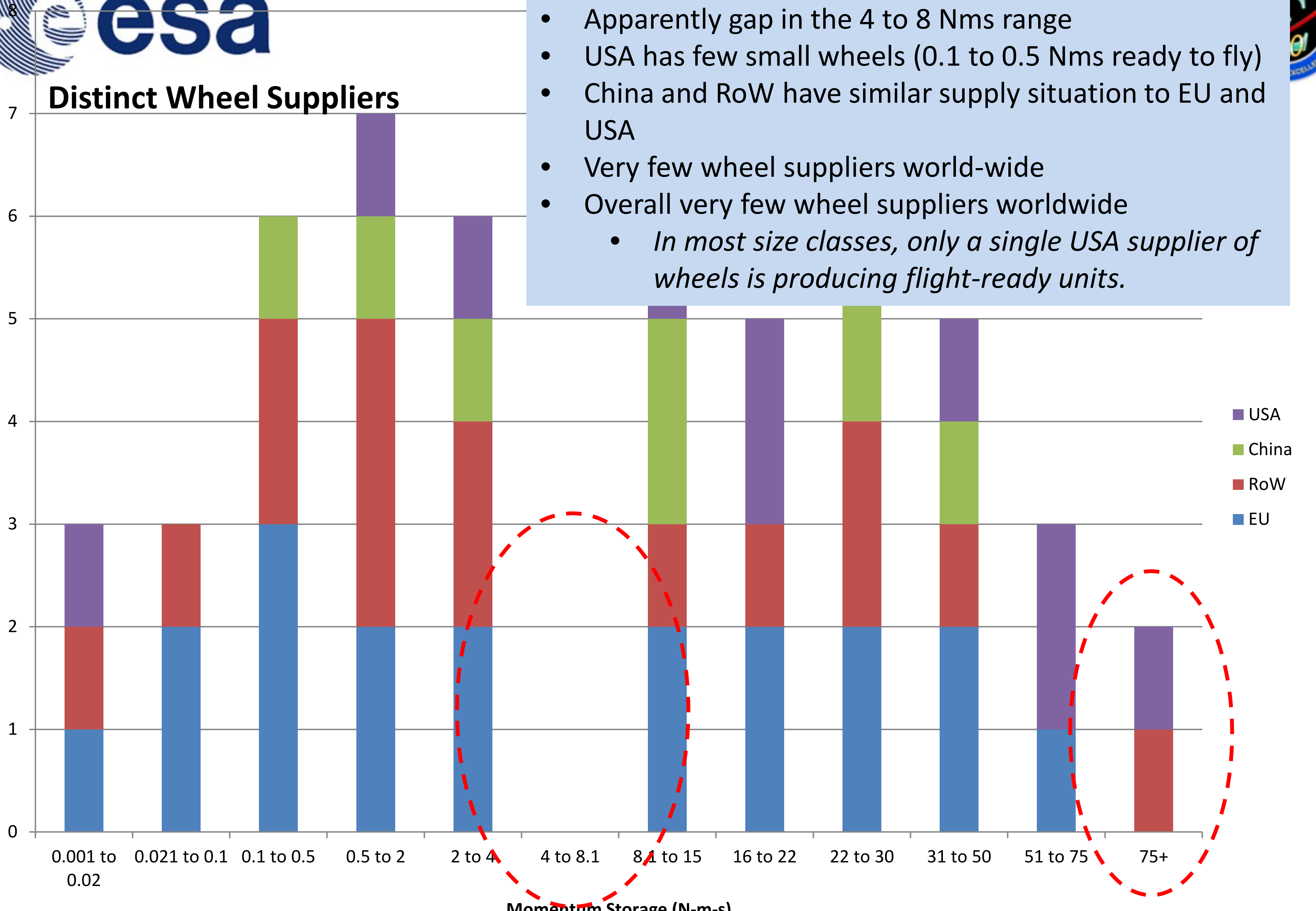
RW Interfaces



- There are a large number of wheels with analog interfaces
  - Dominated by European and Chinese wheels
- There are a relatively large number wheels with Serial interfaces and MIL-STD-1553 interfaces
- CAN, USB etc mainly only on small to nano-sat style wheels.

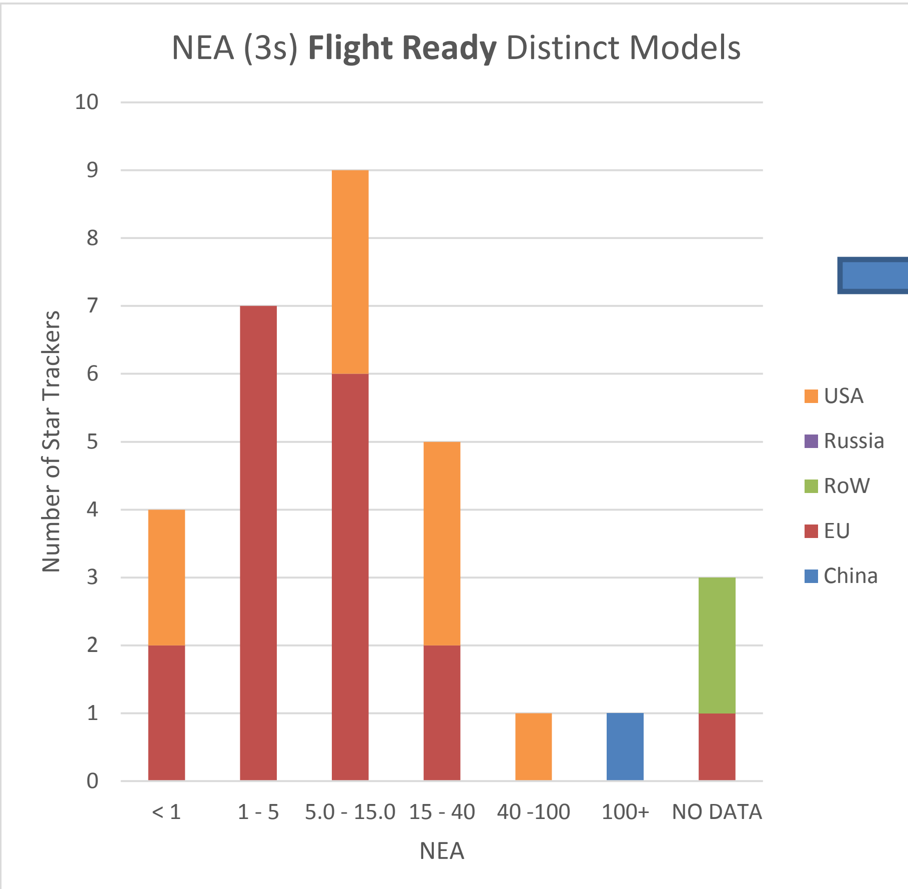
Distinct Wheel Suppliers

- Apparently gap in the 4 to 8 Nms range
- USA has few small wheels (0.1 to 0.5 Nms ready to fly)
- China and RoW have similar supply situation to EU and USA
- Very few wheel suppliers world-wide
- Overall very few wheel suppliers worldwide
  - *In most size classes, only a single USA supplier of wheels is producing flight-ready units.*

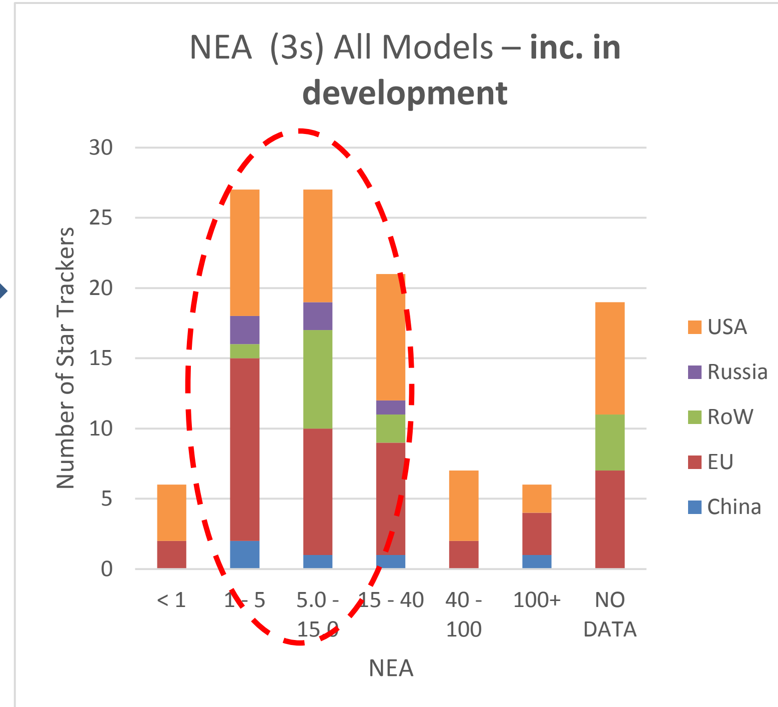


STR Performance

Today

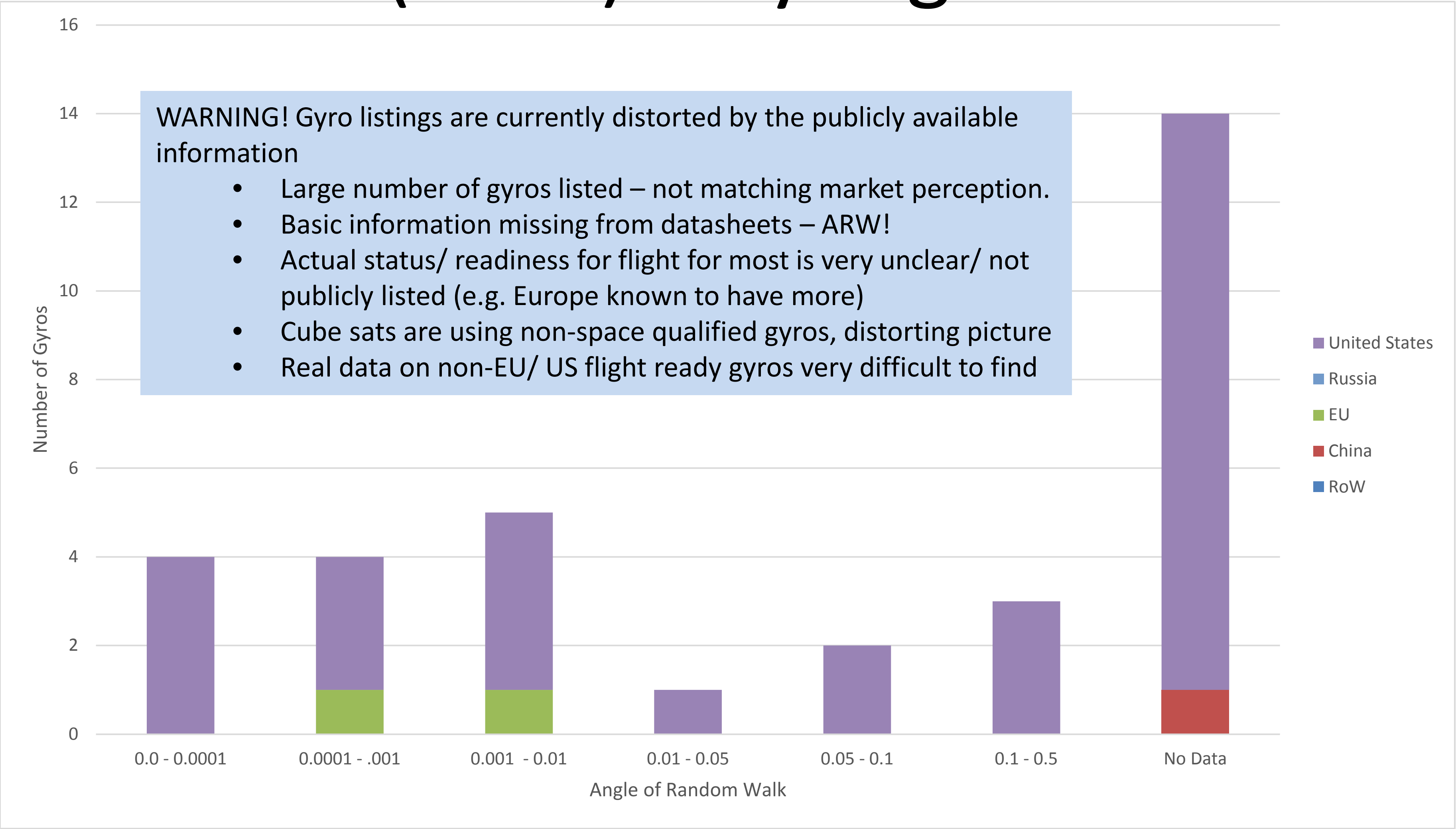


Tomorrow?



- Most new star tracker development on medium performance part of market (largest sales volume)
- Europe **currently dominant** in STR market but clear development of competing products in US, Russia and China.

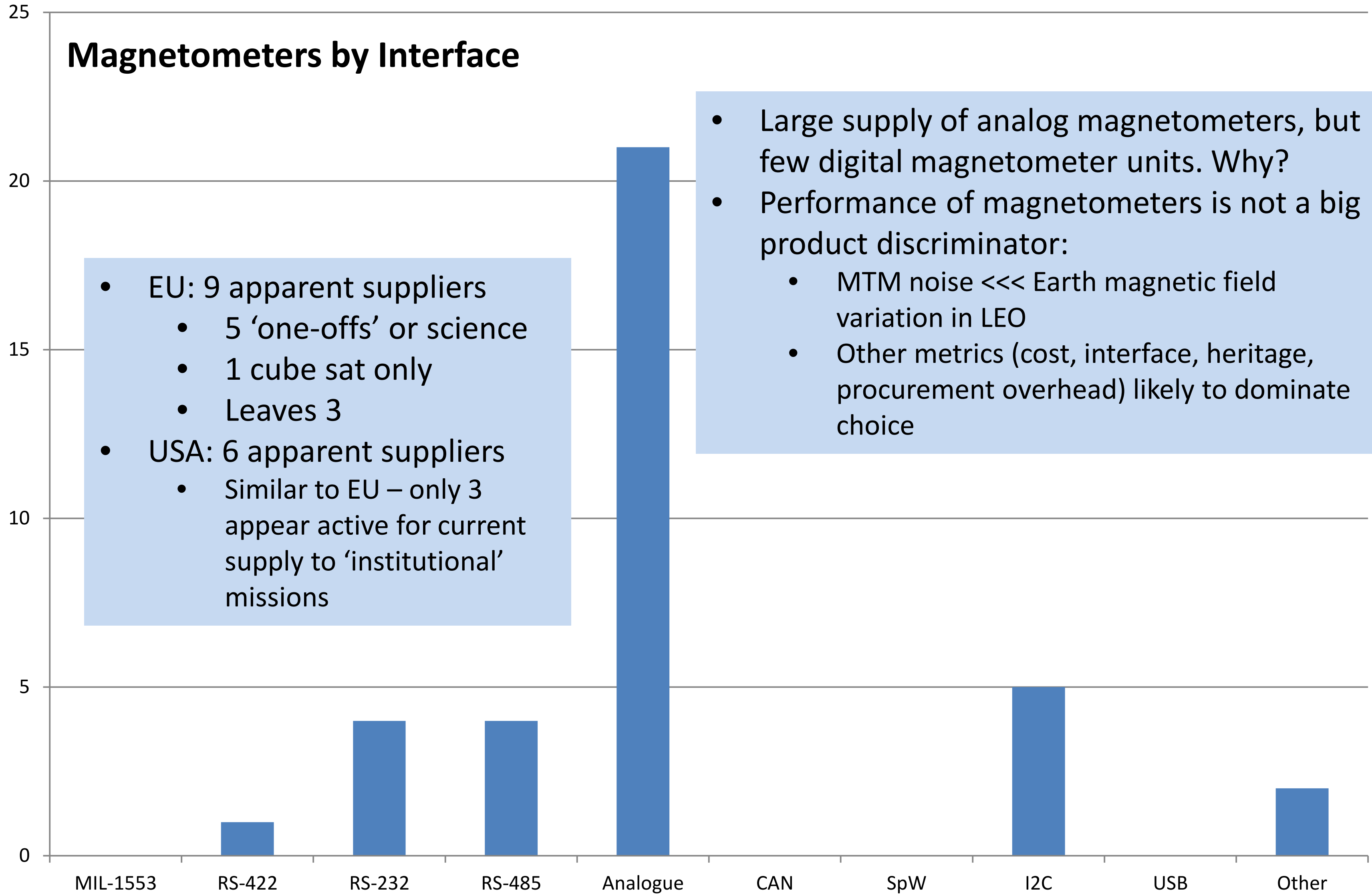
Gyro Performance (ARW) – by region



WARNING! Gyro listings are currently distorted by the publicly available information

- Large number of gyros listed – not matching market perception.
- Basic information missing from datasheets – ARW!
- Actual status/ readiness for flight for most is very unclear/ not publicly listed (e.g. Europe known to have more)
- Cube sats are using non-space qualified gyros, distorting picture
- Real data on non-EU/ US flight ready gyros very difficult to find

Magnetometers by Interface



- EU: 9 apparent suppliers
  - 5 'one-offs' or science
  - 1 cube sat only
  - Leaves 3
- USA: 6 apparent suppliers
  - Similar to EU – only 3 appear active for current supply to 'institutional' missions

- Large supply of analog magnetometers, but few digital magnetometer units. Why?
- Performance of magnetometers is not a big product discriminator:
  - MTM noise <<< Earth magnetic field variation in LEO
  - Other metrics (cost, interface, heritage, procurement overhead) likely to dominate choice

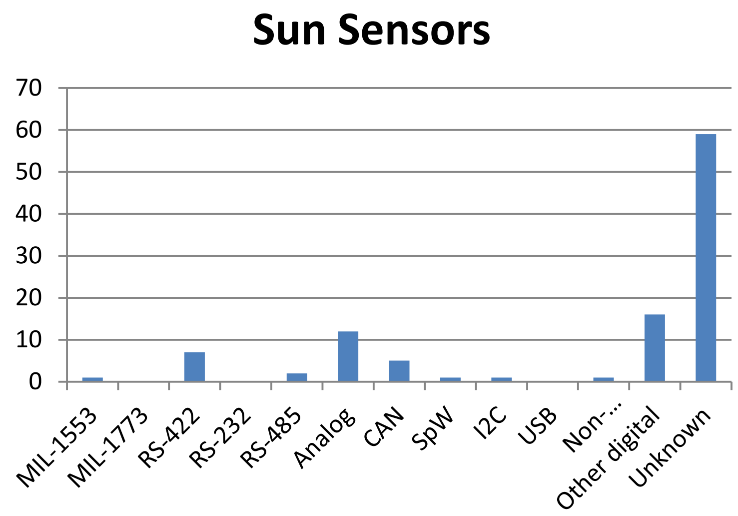
What next?

Current Database Issues/Challenges

- Incompleteness of dataset
  - See, for example, the large number of "Unknown" interfaces in Sun Sensor Interface figure
  - Lack of open source historical data (<2000 many data sheets simply not available in digital form)
  - Constantly evolving/ keeping it up to date
- Lack of 'standard' data sheets information, units, etc.
  - Many data sheets are missing even basic key information (see Sun Sensor plot)
- Language issues & openness issues
  - products from outside of EU/ USA under-represented
- Correctly determining the status
  - In development/ design stage or fully qualified?
  - Obsolete / still available to buy?
  - Only suitable for cube-sats?
  - Company name changes

KEY NOTE:
* Analyses results at the moment limited in accuracy by data completeness

RECOMMENDATION TO IMPROVE:
- Promote a more 'standard' data sheet for each unit – or at least a minimum data set to be included
- True 'open' database to encourage entries from Russia, India, China and Japan – thought to be underrepresented



Future Plans

- Plan to host the open-source GN&C component database on the NASA Engineering Network (NEN) for NASA-internal use by GN&C designers and System Engineers
- Considering ways to make the current open-source GN&C component database available to the public/industry
  - The team has only scratched the surface of the analysis that can be done with this data
  - Looking for a forum that would allow industry to proactively update their respective component information
- Allow the public/industry to submit information
  - Most efficient way to fill gaps and add information as new hardware is produced
  - Some overhead operating costs, for example it will need to be curated – submitters will fill out a prefabricated template
- Challenges/Issues still to be worked out
  - Who hosts the database?
  - US ITAR or Company Proprietary Data constraints
  - Determining the most user-friendly database format:
    - Spreadsheet?
    - Wiki?

Conclusions

- For an apparently simple task there are many challenges and difficulties
- The uses for such a database rapidly go far beyond those initially thought obvious.
- Correctness of the data is key – collaboration and open source seen as the only way to ensure this.
  - Timely and accurate data is foundational.
  - Application of data is unbounded.
- Sometimes the small things are good to collaborate on too – both ESA and NASA saved time and money by collaborating on work both needed to do.

Thank you for your attention!