MAGQUEST

Questions and Answers from the MagQuest Informational Webinar

Questions and answers from the MagQuest informational webinar hosted on April 4, 2019 are now available below. The webinar was intended for informational purposes only, and all information presented here is superseded by the Rules, Terms & Conditions page on the MagQuest website.

For further questions, please reach out to hello@magquest.com.

Submissions and eligibility

Q1: Can participants submit multiple concepts in Phase 1?

- Yes, participants can provide more than one submission, but will need to submit each of these as separate submission forms.

Q2: What level of hardware do you expect to come out of the projects? For example, do you expect the entrants to build and operate the proposed solutions, or just propose paper designs?

- The Phase 1 submission form calls for written concepts, and Phase 2 will call for detailed paper designs (more information will be provided at the beginning of Phase 2). If potential future phases are executed, prototype development, testing and operation of hardware solutions may be required.

Q3: Do submissions need to show preliminary data in order to prove that the idea of the new technique works?

- Phase 1 submissions will be evaluated according to Phase 1 selection criteria, and specifically regarding performance, judges will evaluate the degree to which concepts *could* achieve or exceed the necessary data requirements for production of the World Magnetic Model (WMM). The Phase 1 submission form asks for a detailed methodology, as the emphasis is on concepts, and solvers are encouraged to emphasize *how* their new and innovative concepts would work in the submission form (this emphasis on methodology is particularly important for those with novel ideas that may have less existing evidence to date).

Q4: Regarding eligibility, is the "government exclusions list" based on nationality?

- Please review the Specially Designated Nationals And Blocked Persons List (SDN), published by the Office of Foreign Assets Control, for more information. Links to this list have also been included on the official Rules, Terms & Conditions, as well as in the *Solver Profile* section of the submission form.

The World Magnetic Model, current data and measurement practices

Q5: What is the relationship between the WMM and the International Geomagnetic Reference Field (IGRF)? Is there any sharing of source data and techniques between these two models?

- Mathematically, the IGRF and WMM are similar models, but there are still a number of differences between them. The WMM, produced by NOAA NCEI and BGS, is released regularly every five years, and is actively monitored to ensure that the specification of the model is met.
- The IGRF is an international model, built by approximately eight teams from various institutions, and is under the auspices of the International Association of Geomagnetism and Aeronomy (IAGA). The IGRF is usually released according to a similar schedule as the WMM, but is not subject to any particular specification. NOAA NCEI and BGS contribute to the IGRF by submitting candidate models, but do not manage the IGRF, and the final IGRF model is calculated by averaging models from multiple teams.

Q6: What are the current space assets that are measuring the Earth's magnetic field and are they providing enough timely data, or are there "holes" in the data that need to be filled in? What would be the ideal satellite network for doing this, and is the ESA Swarm three-satellite constellation still providing these measurements?

- There are no “holes” in the current data set.
- Swarm is one source of data for the WMM (as described on the MagQuest homepage). MagQuest is not about filling holes in the data, but rather, it is about finding new and innovative solutions to collect the data.
- Satellites, by design, are finite solutions, so new satellites would need to be regularly launched. CubeSats are an example of a potentially ideal satellite network because they lower the barriers to launching a mini-constellation with a “magnetometer on a box.” In the past, data for the WMM has been supplied by borrowing data from magnetometers that had been installed on big satellites for other purposes. MagQuest is seeking a solution with a dedicated mission, designed with the primary goal of collecting data for the WMM.

Q7: What is the data latency requirement, or in other words, the timeframe from when the measurements are taken until they are presented to NOAA for use in the WMM?

- There is no data latency requirement currently specified, but days to a few weeks would be acceptable.
- The shorter the latency the better, because each new iteration of the WMM is calculated as close to the release date as possible, so that the secular variation is as accurate as possible. To accomplish this, it is preferable to be collecting data until one to two months before the release date. Data latency as high as, for example, six months or one year could be problematic for some magnetic observatories today, because while they produce data very quickly, some of the observatories also have a much longer latency.

Q8: What is the altitude range in space for the WMM? Is it the entire magnetosphere?

- No, the altitude range is not the entire magnetosphere. The altitude range is about 400-800km above the Earth’s surface. This is not a rigid range, but the WMM comes with a well-tested specification that is met in this range. The WMM may remain accurate up to a few thousand kilometers, but at some point there will be effects from magnetospheric currents that would degrade the accuracy significantly. These currents are not modelled within in the WMM.

Q9: Has cell phone data helped improve the current WMM?

- NOAA has an exploratory project called CrowdMag that collects cell phone magnetometer data, and have been collecting such data for several years. This data is not currently being used in the WMM as the quality is not good enough yet, but there are reasons to believe the data quality could be improved in the future, and NOAA is currently exploring this possibility for future applications of the WMM.

Q10: Is the WMM a static model or does it include dynamic effects, such as its response to geomagnetic storms?

- The WMM is a static model, and it does not try to predict response to geomagnetic storms. Secular variation is a time variable, but it is a slow change (much slower than geomagnetic storms).

Additional resources

Q11: Will MagQuest supply sample measurement data?

- The INTERMAGNET website can provide sample data from most of the ground stations. The Swarm data is available to the public, though an account is required to download the data. These two sources should provide a good collection of sample data.

Q12: Is there a place on the website where solvers can identify potential team members?

- Currently there is not a place on the website that provides this information, however this may be provided at the outset of Phase 2. In the meantime, solvers are encouraged to share MagQuest with personal networks, and use the hashtag #MagQuest on social media.

Q13: Is there a list of sensors that "work well" that can be made available to the group?

- No, a list of sensors will not be provided, because a Phase 1 concept could conceivably describe a sensor or data collection solution with an estimation of where the magnetometer would go. In Phase 2, solvers will need to develop detailed designs for the more integrated, full solution, but there will also be an option to expanding teams at that point, to collaborate with other interested solvers who may have complementary expertise.

Target performance metrics

Q14: How many measurements and what geographic locations (latitude, longitude) are required for a full characterization of the magnetic field? Do these measurements need to be made contemporaneously?

- The provided Target Performance Metrics cite 162 points as an example of a sufficient number of homogeneously-distributed points for measuring geographic distribution. This number is currently being validated and updated with more recent data by NCEI. The goal is to develop a more recent estimate but a big change in the number is not expected. Geographic location depends on whether the data is being collected on the ground or in orbit. For data collection in polar orbit, it is possible to use all the data in the orbit, so the requirement is mostly regarding longitude sampling. For data collection on the ground, it is a question of both latitude and longitude, as there are areas where making measurements is more challenging, such as in the oceans.

Q15: Over what period of time should a complete magnetic field set of measurements be made? This would determine the minimum on-orbit life for a very low-cost constellation of CubeSats to make these measurements.

- The minimum requirement stated for the measurement time interval in the Target Performance Metrics is three years of data, because this is the duration used at NCEI to calculate the WMM. A long enough time span is needed to accurately calculate the time derivative of the magnetic field, which is crucial to forecast five years of data into the future. With more data, longer time spans can be used, and in some situations, this can increase the accuracy of the forecast calculation.
- Publication dates for the WMM are set at five-year intervals (e.g., for 2025, 2030...) and an absolute minimum of three years of data are required for the model to be produced, but a constant source of data would be preferable, as it would allow the ability to test the model during the other two “off years.”

Q16: Regarding the target performance metrics, specifically accuracy and precision, what is the "geographic frame"?

- Magnetometers in space can achieve very high accuracy but need be correctly oriented so you know the attitude. This accuracy requirement includes both the magnetometer instrumental accuracy and the attitude accuracy. Once the data has been rotated into the geographic frame, it is preferable to have an accuracy better than 5nT per component.

Q17: Is the 5 nT and 1 nT accuracy and resolution requirement at the Earth's surface or at the measurement location (i.e., for aerial or spaceborne applications)?

- At the measurement location.

Q18: Are you expecting the data feed to be a) ongoing and continuously renewed, b) in timed intervals, or c) depends on the design?

- A lot of data gets thrown out due to noise (about 90% of satellite data cannot be used) so for that reason more data is often preferable. But it also has to do with the resolution of the model. So, for the WMM which describes the large-scale components of the magnetic field originating from the Earth’s core, we don’t need such high-resolution data in space, as for example, crustal field models. That being said, this is mostly relevant to satellite data. For observatory data, there is different processing, and less data would be discarded because

more data is needed to figure out the disturbances, in order to come to a good estimate of the field coming from the Earth's core.

- If the question is about data collection and transmission to NOAA, low cost data delivery options should be explored.

Q19: Are there areas on the globe where coverage is less important (given the end users of the WMM) either in re-visit frequency or in spatial resolution? How important is the polar region coverage?

- The WMM Military Specification (Mil-Spec) outlines the coverage NGA is required to meet. As an overview, 55 degrees north and above are measured as one region; 55 degrees south and below are measured as another region; and the entire globe is a third region. For each of those regions, the error needs to be under one degree. Due to this approach, polar coverage is more important to meet the Mil-Spec, but other regions should not be excluded.
- The WMM is a global model that is used everywhere and no region is discounted. Any significant geographic gaps will impact the accuracy of calculating the WMM, and it is important to have geographically homogeneous coverage.

Aerial solutions

Q20: Why are you replacing the satellite? Are you willing to go back to aerial?

- Yes, in the past aerial measurements have been used. Magnetometers were attached to the back of aircraft, but the operational costs were too high; however, this may no longer be the case. A feasible aerial concept, such as a fleet of solar-powered UAVs that could hover over different parts of the globe, could be a submission to MagQuest.

Q21: Any platform other than a satellite seems to be more localized in terms of data acquisition, and having global coverage (i.e., UAVs) will likely be more time or resource consuming. How can we make sure airborne and terrestrial surveys are comparable to satellite?

- That is certainly a challenge with UAVs, sea-based systems, or ground-based systems on their own. Ultimately, the goal is global coverage and solutions should address ways to mitigate coverage gaps. For example, with solely ground-based sensors on land, gaps would be present in the ocean (and vice versa). It is possible to team up with other participants to help mitigate coverage challenges.

Terrestrial solutions

Q22: How many ground observatories are used?

- The INTERMAGNET website lists all ground observatories and locations (e.g., see List of IMOs and Responsible GINs). MagQuest's Additional Resources page provides additional relevant information. Also worth noting, magnetic observatories are currently used for both validating the model and calculating the model. The BGS typically uses 100-120 observatories to calculate their version of the model.

Q23: For terrestrial observatories in particular, do you currently do processing across multiple disparate locations to help differentiate local field effects [crustal biases] from the actual Earth magnetic field? Or is the current per-observatory processing limited to a single observatory?

- Assuming this question of "local field effects" probably refers to crustal biases — yes, we need to know what the effects of the crustal field are at the observatory location before being able to calculate the WMM. Fortunately, we already do know the local field effects at existing observatories, because we have very good satellite data over the past two decades, so we are able to accurately calculate this crustal bias from recent satellite data by calculating models using both satellite and observatory data. If, however, a solver proposes new observatories, it would be important to propose a method for how they would determine the crustal bias.

This could be done as long as we have a satellite in space such as the SWARM mission, and this is information we could use in the future.

Q24: What is the difference between Earth's magnetic field from local effects, such as metal and current?

- In a terrestrial observatory, the observation site is kept magnetically clean and this typically removes local effects. It is the responsibility of the observatory to ensure this magnetic cleanliness. It is challenging for an observation site to remain clean over time, and this is why there are not so many observatories.