# GMT Steering Committee Report

August 18, 2016

### *Introduction and Background*

GMT is an open source collection of about 80 command-line tools for manipulating geographic and Cartesian data sets (including filtering, trend fitting, gridding, projecting, etc.) and producing PostScript illustrations ranging from simple x–y plots via contour maps to artificially illuminated surfaces and 3D perspective views; the GMT supplements add another 40 more specialized and discipline-specific tools.

GMT is used by scientists all over the world to make publication-quality maps and plots. The community includes more than 25,000 individual users and the GMT web site has more than 20,000 visits per month and roughly 2000 downloads per month [*Wessel et al*., EOS, 2013]. Google Scholar shows 11,500 citations from journal articles but many authors cite GMT in the acknowledgements or provide no citation or acknowledgement. These tools are also heavily used by researchers in government labs (e.g., USGS, NOAA, and NASA) and industry for both operations and research and development. Moreover, GMT provides the software foundation for higher-level tools used by the scientific community including MB_System [ref] and GMTSAR [Sandwell et al., 2011].

GMT is developed and maintained by a group of 5 core developers (Table 1 and Figure 1) with assistance from volunteers from the global user community. The core developers leverage the skills and dedication of accomplished scientists and developers from around the world. This small development group has been very successful using this business model for over 20 years. This development comes at a very low cost to US funding agencies. Specifically, of the five main GMT developers, three of the most active participants are European scientists and the fourth is at a US Government lab and hence his time and the support of his IT team come free to NSF. Only PI Wessel has salary funding from NSF but as Professor he is mostly supported by the State of Hawaii.

**Table 1.**

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| **Joaquim Luis** is a Professor at the University of Algarve, Portugal, working on marine magnetics, plate kinematics, tsunami modeling and scientific software development. He is a GMT developer as well as the developer of Mirone, a GUI type interface for GMT on Windows. |
| **Remko Scharroo** is a Remote Sensing Scientist at EUMETSAT, the European Organisation for the Exploitation of Meteorological Satellites. He works on the definition and validation of altimeter data products and algorithms, and particular interest in the monitoring of sea level rise. He developed and improved several elements of the GMT code, among others dealing with gridded data and the PostScript engine. |
| **Walter H F Smith** is a Geophysicist at NOAA, the (US) National Oceanic and Atmospheric Administration. His current research focuses on satellite radar signal processing to enhance applications in marine geophysics, physical oceanography, cryosphere science, and weather and climate forecasting. He is the co-founder, with Paul Wessel, of GMT, and is co-author with David Sandwell of the “Smith and Sandwell” method of estimating ocean depth from satellite altimetry. |
| **Paul Wessel** is a professor at SOEST, U of Hawaii at Manoa working on plate tectonics and scientific software development. He is the main developer and maintainer of GMT, as well as a contributor to GMTSAR. |

**Florian Wobbe** is a geophysicist at the Alfred Wegener Institute for Polar and Marine Research in Bremerhaven, Germany. He worked on plate-tectonic reconstructions of the Southern Ocean and joined the GMT developer team in 2011. He added CMake build system support, compression and tiling via netCDF-4 and integrated external FFT libraries.

**Figure**. GMT Development Team and Steering Committee during a meeting at SIO August 15-19, 2016. Steve Diggs (upper left), Khalid Soofi (upper right). (lower left to right) Paul Wessel, Kurt Feigl (visiting developer), Dave Caress, Walter Smith, Joaquim Luis, Florian Wobbe, Remko Scharroo, Dan Bassett, and Davisd Sandwell (Soofi will send updated figure with mug).

***Funding***

The US part of the GMT development has been funded continuously since 1993 mostly by small grants from the Marine Geology and Geophysics (MG&G) program at the National Science Foundation (NSF). This funding continued until 2015 although the MG&G program managers encouraged Wessel to seek funds from other NSF programs to better reflect the wide usage of this software. More recently Wessel, Feigl, and Sandwell received 4 years of funding (2013-2017) from the NSF Geoinfomatics program to further develop GMT and GMTSAR for applications outside of the traditional area of MG&G.

Most recently Wessel submitted a 5-year proposal that achieved very high ratings by the reviewers and panel. Several program managers at NSF including Barbara Ransom and Russ Keltz discussed stabilizing the support for GMT by moving it out of the area

research funding and into the area of operations. NSF plans to fund the first 2 years of GMT from MG&G and then move it into a more sustainable model for the last three years.

Since GMT has become an essential tool for many research activities, the program managers and science community would like to see this activity transition from a PI-driven effort with sporadic funding into a community-driven effort with more stable funding. A significant concern is that the PI and several of the developers will reach retirement age over the next decade and there is no succession plan to maintain the activity further into the future.

### *Steering Committee*

In order to move in a direction of a sustainable activity, Wessel proposed to establish a GMT Steering Committee of peers who will be charged with the task of overseeing and guiding the practical aspects of the transition. David Sandwell, Scripps Institution of Oceanography (SIO), agreed to initiate this committee and his key task was to assemble a technical group of GMT-aware scientists, across a range of ages and disciplines, to guarantee a competent and pro-active committee (Table 2 and Figure 1). To avoid adding new costs, Wessel proposed that this committee should meet annually with other available GMT developers.

This report summarizes the first meeting of the GMT Steering Committee and Developers at SIO during August 15-19. Travel support was provided by the University of Hawaii (UH) using NSF funding as well as support from UNAVCO for a GMTSAR Short Course at SIO prior to the GMT meeting. Dave Caress received travel support from MBARI to join the Steering Committee. The main tasks of the steering committee are to:

- monitor the overall status of the GMT program;
- provide guidance on the direction and scope of the technical development;
- provide guidance on staffing of the non-volunteer aspects of GMT development
- provide guidance on funding; and
- provide guidance on a succession plan.

**Table 2.**

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| **Dan Bassett** is a postdoctoral researcher at Scripps working on the structure of the overriding plate at subduction zones. He works mainly with refraction seismic data, graviy anomaly data, and bathymetry data. He earned his PhD at Oxford in 2014 working with Tony Watts. |
| **Dave Caress** is a software engineer at MBARI working on seafloor processes including tectonics, sediment transport, and subsurface structure. He is the co-author of MB-System, which is an open source software package for the processing and display of swath mapping sonar data. |
| **Steve Diggs** is a computer scientist at Scripps. Diggs and his team archive and manage hydrographic data, including physical and chemical measurements, and maintain links with international colleagues for coordinating global data sets. He is the PI on an NSF EarthCube project. |
| **Khalid Soofi** (Soofi) is a science fellow at ConocoPhillips working on a full spectrum of remote sensing projects ranging from geological and geomorphological analysis of |

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| images, image processing for logistics, mapping and engineering applications as well as environmental baseline studies. Soofi earned his Ph.D. in electrical engineering from the University of Kansas. |
| **David Sandwell** is a professor at Scripps working on seafloor tectonics using marine gravity and bathymetry. He is a co-author of GMTSAR used for measuring crustal deformation with radar interferometry. |

***First Meeting of Steering Committee and Developers***

The first two days of the meeting, the Steering Committee and developers met and discussed all aspects of GMT. Links to all of the presentations are provided in this document. Paul Wessel began the meetings with an overview presentation on the State of Generic Mapping Tools. The outline of his talk was:

- Status of GMT;
- The Public GMT API;
- GMT 5.3 Release August 19, 2016;
- Funding Situation;
- Development Plans;
- Post-Doctorate Search; and
- Succession Plans.

During the second day of the meeting the Steering Committee made presentations on their uses of GMT as well as their views on the future of GMT. The presentations were:

- Khalid Soofi – GMT Applications & Future Improvement Suggestions
- Dan Bassett – GMT and the structure of subduction zones
- Steve Diggs – The Future of GMT?
- Dave Caress – MB-System integration with GMT
- David Sandwell – Applications of GMT: SRTM15_PLUS and GMTSAR

A poorly edited set of notes from these meetings are provided in the Appendix.

***Recommendations***

Based on these presentations and discussions the Steering Committee has arrived at the following Recommendations:

1) Provide more examples for each of the GMT tools. These should be available with the man-pages so users can find and execute simple, commonly used examples. Encourage users to submit examples and enable rating and ranking of examples (6 mo).

2) Develop a Stack-Exchange like (http://stackoverflow.com/) question and answer like forum. (1yr)

3) The transition from GMT4 to GMT5 has been a major challenge for much of the user community. Continue to maintain GMT4 until downloads are small. The development team should also provide easily accessible tools and simple examples to foster that transition. (6 mo)

4) Maintain a focus on the core aspects of GMT related to gridding and publication-quality display of data.

5) Capture statistics on GMT downloads from all the major package managers (if possible) to better understand the users. (1 yr)

6) The development team should work more closely with the EarthCube community on automated ingestion of standardized web-based data delivery resulting in an EarthCube proposal. (1-2 yr)

7) Tools should be added and improved to better integrate GMT grids and vector data with other commercial programs (e.g., ARCGIS). (1 yr)

8) Changes to the GMT tools as well as the API should be minimized especially for those elements that are used for integration by other packages.

9) Continue to seek enthusiastic participation from the wider research community through short courses and workshops.

10) Hire a post doctorate researcher to maintain the core programs and also assist in the integration of the GMT API into Matlab, Python, Julia and other emerging languages. (6 mo)

11) The overall GMT development should be separated into two activities. The testing and distribution of GMT should be moved to an operational center such as UNAVCO. The research, development, and maintenance aspects of GMT should remain with the development team. (5 yr)

12) Capture a history of the development and inner workings of GMT to provide a sustainable knowledge base. (Smith and Wessel, 5 yr)

***Appendix***

These are notes of the GMT steering committee meeting on August 15, 2016, 8:30 until 11:30 am. **Boldface highlights possible action items or recommendations.**

We started the meeting with around the room introductions including all the developers and the steering committee. There were several points that were brought up during the introductions and in particular Walter Smith talked about the following challenges.

- Volunteers are a challenge because they don't get paid so they are difficult to manage.
- Sandwell also said we need to connect with the NSF EarthCube community.
- One of the challenges is that GMT has a steep learning curve. Walter Smith said that when GMT was developed it was not intended for sissies.

Paul Wessel made a presentation that is linked to this document. The outline of Paul's talk was:

- Status of GMT.
- Public API.
- Release of GMT version 5.3.
- Past and current funding.
- Plans for development of GMT.
- Plans for hiring a post doctorate researcher.
- Succession plans.

**While one can track the users that FTPs directly into the GMT site, it is not possible to track the downloads from the package managers. This is probably the bulk of the downloads.**

**Walter Smith suggested that we need an oral history from the current developers in order to capture the details that are deep in the computer code.**

**There was a discussion about walling off the name GMT** since there are other organizations that use that same name and it would be unfortunate if a large organization such as the biological research community capture that name and dominated it on the Internet. There was some discussion of talking to the UCSD technology office in order to determine how to keep that name as part of GMT.

There was some discussion that we need more examples for the novice user. Test scripts that exist currently could serve as these examples. There was some discussion that one could paste these example programs to the end of the man pages to provide the user with extra information.

There was some discussion about the reasons for moving from individual module names such as ***triangulate*** to compound names all starting with gmt such as ***gmt triangulate***. This is done to avoid duplicate names in the executable namespace. There was discussion of the improvements that are coming along for GMT. These include: making API's for Matlab, Python, and Julia. The GMT developers need to hire the right person to do these jobs.

There was some discussion about passing data objects through memory. You can pass

entire files of information through memory but what happens when the computer crashes? Is there a way to recover the intermediate products of the processing after the crash? The developers noted this would be difficult and perhaps not worth the programming effort.

There was some discussion about the need for a simple example of how to read and write a net CDF files from GMT using new API.

Funding. Paul discussed the funding. This is documented in his keynote address. Basically GMT-Hawaii has been small grants provided by the National Science Foundation from Marine Geology & Geophysics. More recently Paul, David Sandwell and Kurt Feigl wrote a proposal to the NSF Geo-informatics program. They were instructed not to include ocean applications in the proposal but all other types of applications. This proposal was very highly ranked but the program manager recommended a 10% cut. The developers Wessel, Sandwell, and Feigl came back and asked for a fourth year of funding to make up for that cut and NSF agreed. The latest MG&G proposal (2016 to 2021) was very highly ranked and it was recommended for five years of funding. Two years of this funding upfront from the MG&G program. The managers were Barbara Ransom and Russ Kelz. The following three years of funding would come from another undetermined source and perhaps that would be the UNAVCO/NGEO frontiers proposal activity that is being developed now.

The steering committee should look at the NSF proposal and especially the summary because it explains where GMT is going in the next five years.

**Again there was more discussion about capturing the details of an oral history of GMT using something called a multimedia handbook.**

There was some discussion that the steering committee could help identify things that shouldn't be done in the future by the developers. For example should GMT use the Open Street Map OSM or should they continue to develop their old coastline file software.

This Wednesday the developers will begin to interview five candidates for the postdoc search. One of the objectives is to find a postdoc that's a good programmer perhaps also a good scientist. In the long run the developers need hire, or find from within, a person that can eventually replace Paul Wessel as the scientific leader of the GMT development.

Succession plan. The succession plan involves three components:

1)host the GMT software distribution and testing;
2)bug fixes and maintenance to keep the software current; and
3)further development of software capability. This will require a person who understands both the science and the inner workings of GMT in order to develop it into the future.

These are notes from the GMT steering committee meeting on Tuesday, August 16, 2016, 8:30-12:00

The first speaker was Khalid Soofi who discussed uses of GMT in his working environment at ConocoPhillips. His presentation is linked above. Soofi explained that

they use every-available software including software that has expensive licenses. Nevertheless GMT has unique capabilities that are not offered by any other software. The heart of GMT are two programs ***blockmedian*** and ***surface*** and these are used to grid randomly distributed data into very fine grids. They are industrial-strength programs. The way Soofi uses GMT is that the output is sent into other programs using translators. The results are finally imported into ARCGIS to send off to the rest of the company. Soofi showed his TCL/TK app application for running GMT. He uses this because he uses GMT infrequently so cannot remember the details of the GMT commands so he has these automated examples.

Sandwell suggested that we capture those built-in programs because they represent the most common usage of GMT. **Then place these examples at the end of GMT of man pages so they can these shown to other users they're very straightforward simple applications.**

Soofi had two items on his wish list for GMT.

1)The first was to load examples of GMT usage at the bottom of each man page or a simple examples this is been already recommended once and should be a highlight of the report.

2) The second on his wish list was better integration of GMT into ARCGIS. This would include both grd-image to geotiff conversion as well as vector and polygon conversion to shape files.

The next presentation was by Dan Bassett he is a postdoc at IGPP working on marine geophysics mainly at subduction zones. Bassett showed many example uses of GMT and there were a few examples that the GMT developers would like to highlight in their cookbook or their example book. The first was a plot showing histograms on both the horizontal and vertical axes along with a color image in the center. It would be good to show this example using both GMT4 and GMT5, so the users can see how to translate between the two systems. One thing Bassett does is to use Adobe Illustrator for the final editing and tweaking of all the postscript files.

The second item that was highlighted in Bassett's talk was the use of GMT for display of seismic imagery. Again there were some nice examples that should be put into the GMT cookbook. The seismic examples illustrate that GMT could be expanded into seismology. This could be important for the upcoming NGEO proposal where Iris and UNAVCO need to collaborate more.

Notes from Dan Bassett after the meeting.
A couple of things that struck me during the meeting:

1 - GMT4 vs. GMT5
Before the meeting, it wasn't clear to me if GMT5 was replacing GMT4 or if both will continue to be developed and maintained. I think the release scheduled for friday has updates for 4 and 5? I also wasn't aware that there were already modules to convert scripts using GMT4 to GMT5. Changing from 4 to 5 is a big deal for people who have hundreds of scripts using GMT4, so any modules that make this transition easier should be advertised.

2 - Examples
I agree with you that it would be really helpful if there were more examples attached to

the man pages. It would be great if the community could upload example scripts and images to the man pages. This may be a bad example, but lots of websites for accommodation/shopping have sections where users and leave comments and reviews. Subsequent users then identify what reviews were the most helpful and the top 3 are shown on the main website. The rest are off on a separate page somewhere else where you can scroll through them if you want to. I wonder if a similar system could work for GMT examples, with the top example demonstrating different features is shown on the man page with the others somewhere else?

3 - Succession plan. I think a key part of this should be trying to reduce the perception that GMT is really difficult and has a steep learning curve. I don't think people are intimidated by writing scripts, it's just that getting the GMT syntax right is tricky when you first start. I think a set of 10-20 well crafted example scripts that show off the basics and an accompanying <40 page tutorial document could be extremely useful for new users. This tutorial should be separate from the cookbook (currently >240 pages) and just step a new user through installation, and then sequentially through each script describing what it's doing in simple terms. There could even be an accompanying example dataset. People are very impatient, so it's important new users can run something and prove to themselves that it works quickly, or they will move onto something else like Arc-GIS. Finally, I don't think a GUI is the answer. People will use this without looking at scripts and will either think that it represents the full functionality of GMT, or they will ask for it to be developed so that it does.

The next presentation was by Steve Diggs and was entitled the future of GMT? The main focus of his talk was to show where GMT fits into the larger world of research and data distribution. Diggs noted that most of the data that we use in the research world is available on the web through web applications. The NSF EarthCube program has significant funding and the focus of that program is to make that web-based data available to research users and the general public. Diggs showed some nice examples of Ocean Data View, which has more than 40,000 users. Diggs noted that they started using group Google Earth APIs for some of the applications but Google changed the structure such that these applications would no longer work. Diggs also noted that while Earth cube is a very visionary program, it did not have much success in the first few years of operation so during the next five years there moving towards smaller and faster and more web-based applications.

During the discussion Soofi emphasized that one of the strengths of GMT is that it doesn't depend on a lot of other types of software and in fact the number of dependencies should be minimized during further developments. So there will be major trade-offs between adding external libraries to link with outside developments (e.g., Open Street Map or ARCGIS) and keeping the GMT package less dependent on outside software that is sometimes a moving target.

The next presentation was by Dave Caress. Dave is one of the principal authors of MB-System software. Dave noted that MB-system requires GMT to operate. His presentation is summarized in an e-mail linked above. He noted that there is good communication between the MB-system developers and the GMT developers and that's essential for understanding how to move both developments forward.

Dave Caress had two very specific requests for the GMT developers.

1)The first request was to build something into GMT that looks for an MB-System

config file where one can find where the MB_system library exists. This feature is needed for seamless operation of MB system in the GMT environment.

2) The second request was that the GMT developers don't change the interface with the APIs as this will break the MB-System software as well as other software.

The final aspect of Dave's presentation was to go through a number of image display applications build on X11. MB-System has some nice tools for displaying netcdf files were you can rotate the object in three dimensions. It also has the capability of changing the shading, intensity, and color in real time something that not available in GMT. **Should this image display capability be ported into GMT?**

Notes from Cave Caress after the meeting.

I'm not sure that it belongs in this report, but the release of GMT 5.3 will be followed in the not-distant-future by an MB-System release implementing the GDAL/GMT approach to embedding projection information into grids. In turn, this will enable using grdimage to generate proper geoTiffs, and allow me to retire the program mbgrdtiff. This progress is due to my spending a small amount of time with Joaquim this week. The programs mbswath and mbcontour will remain as true GMT modules; I'm hoping I'll be able to get my autotools based build system to install these in the location specified by GMT, but I haven't figured that out yet.

With respect to the succession problem, I have some thoughts but not solutions.

GMT is fundamentally an infrastructure allowing for creative and innovative data processing and display, and therefore well suited for use in science. Many software packages allow one to easily do things people have thought of before; GMT allows one to easily implement new ideas. The reason that GMT has this sort of utility is that its authors developed it to support their own science.

The team can, and should, plan for long term software maintenance beyond their involvement. The effort required for maintenance can be accurately scoped, budgeted for, and funding sought. We should recommend that the team seek to arrange for long term maintenance by approximately the time of Paul's projected retirement.

The future of GMT as a "living" software project - that is, continued active development with significant new capabilities - depends on something that can't really be planned for. GMT will continue to be actively developed only if it is taken over by one or more new scientists that work on it in the same way that Paul, Walter, Remko, and Joaquim have over the past decade. Useful development will depend on somebody adding new capabilities to support their own work, and simultaneously taking responsibility for the viability of the whole package.

The GMT postdoc approach is worth doing (particularly since it is funded!), but I am very skeptical that this will wind up producing the next generation of GMT principal developers. The problem is that a postdoc centered on GMT seems unlikely to me to result in a academic scientist with a viable career. Fortunately, I am usually wrong when making predictions of this sort, and anyway the postdoc(s) will have significant short term benefit to the project. So, I think we should be encouraging with regard to the postdoc approach, but we should be clear that this is unlikely to solve the succession problem.

Those are my thoughts for now.

The final presentation was by David Sandwell where he discussed two uses of GMT in their lab.

The first use was in the development of a global bathymetry grid called SRTM15_PLUS. In that development, there are two main programs that are used to grid the ½ billion sounding data points. These are the programs ***blockmedian*** and ***surface*** and he noted they run flawlessly with the huge data set and large output grid of 20,000 by 20,000 cells.

The second item noted by Sandwell was the use of a function called grd2kml to convert netcdf files in the KML files for Google Earth. This functionality is enabled by the programs ***ps2raster*** as well as ***grdimage*** in order to make this conversion.

Sandwell then went on to talk about application called GMTSAR. This is a package of programs and shell scripts that create radar interferograms from synthetic aperture radar dat. He showed a flow diagram where there was one part of the workflow depended on custom software and the latter part of the workflow depended on GMT software. The GMT API was used to interface these two sections of software. Wessel and Sandwell sent pre-proposal too UNAVCO to provide support for both of these packages. The main support items are:

- Provide support for the development of GMT at the University of Hawaii and GMTSAR at UCSD.
- Validate and upgrade software through extensive testing on the commonly-used UNIX platforms;
- Develop and distribute high-level workflows for GNSS and InSAR integration and time series;
- Streamline the distribution of these packages by hosting them with the major package managers (e.g., apt-get, yum, fink, macports,...);
- Maintain developer and user forums for feature requests and provide a bug tracker;
- Host software development workshops for guidance and construction of new tools; and
- Host short courses on the usage of GMTSAR and GMT for processing geosciences data from NGEO archives.

Sandwell highlighted three challenges or wish list four GMT. The first was enabling the community to painlessly convert from GMT4 to GMT5. To make this adjustment the community needs simple examples as we discussed previously these could be included at the ends of the man pages. A second request was that sometimes the program GMT continues to run even after the program's been killed. The developers are looking into this issue and also have noticed the same thing. The third item requested by Sandwell or noted by Sandwell is that there's commonly a misuse of inches and centimeters such that the programs are the images come out in the wrong size and shape and this is really a user issue but it's still a fundamental problem. The fourth item noted by Sandwell is that he doesn't understand the GMT config file very well and has some 300 lines of configuration.

The final discussion item on the second day was that Sandwell will write up the notes and circulate them to the committee. The committee will review the notes develop recommendations and write a draft report the committee will also rank these were recommendations. Finally the committee will deliver the report to the developers on Friday morning and so there can be just some discussion after the delivery with the developers as a wrapup of the weeks activities.