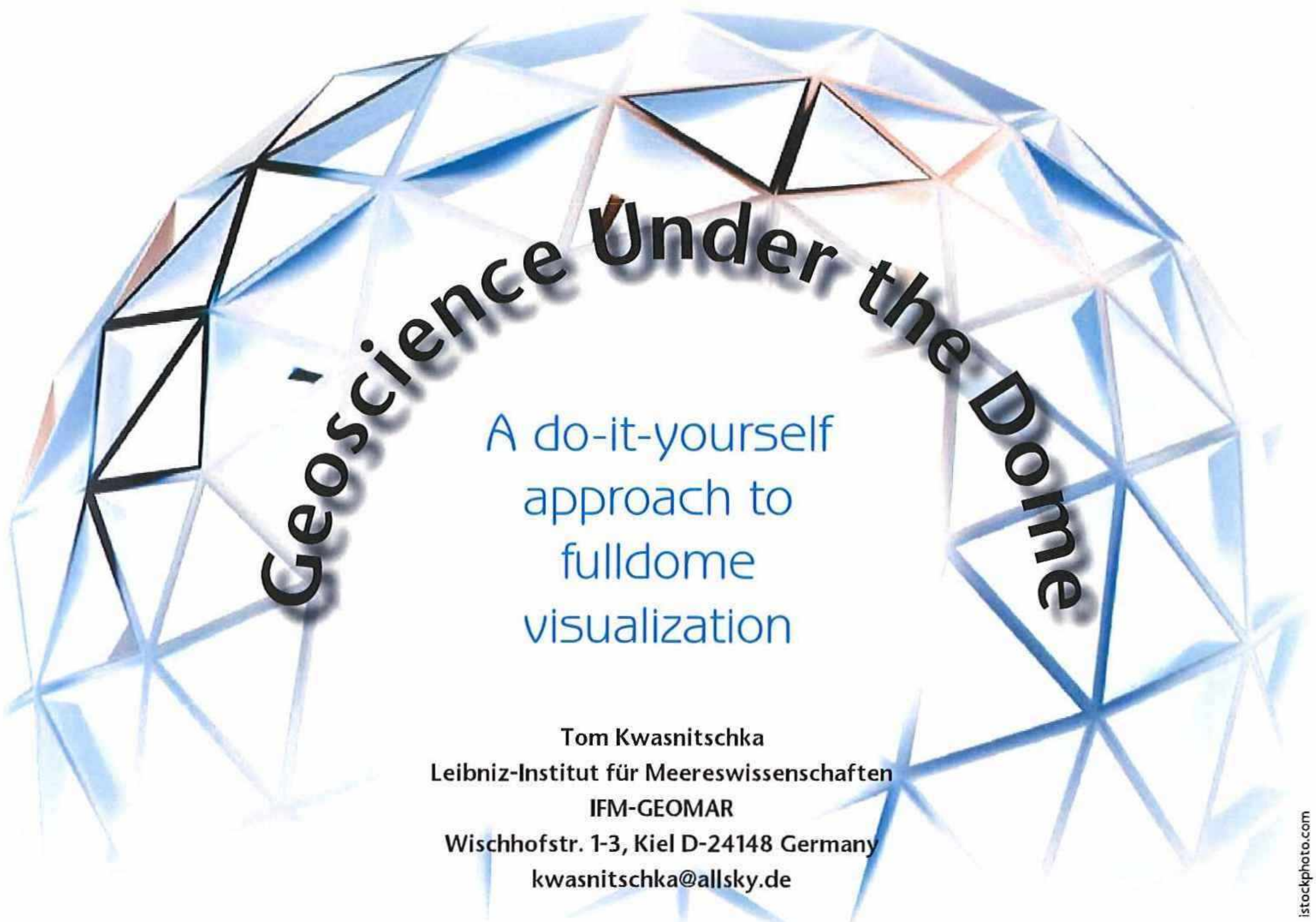

Geoscience Under the Dome

A do-it-yourself approach to fulldome visualization

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Originating out of a masters thesis of visualizing geoscientific data in a dome environment, the author not only created the datasets, but also designed and built the dome and projection system on a limited budget with emphasis on quality. Cooperation with two major vendors provided two independent solutions for image generation. This article is an account of how the dome and the projection system were conceived, followed by a discussion of the used software and the scientific content developed for it. Rather than to serve as a dome construction tutorial, this text shall be an entertaining account of using some of the established fulldome tools.


Tom Kwasnitschka

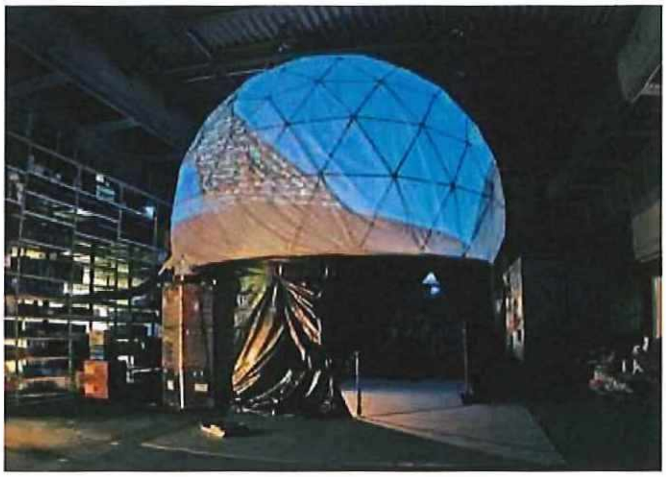
Besides my work as executive associate of the image agency allsky.de, I am a master's student of geology specializing in volcanology. I was only truly introduced to the possibilities of real time astronomical data visualization during the Zeiss Innovation Days 2005. There I met Staffan Klashed, proud father of the Uniview software, and we instantly started a discussion on transferring the idea of domed science visualization to the geosciences, compiling something like a digital Earth atlas.

As time went on, I started looking for a topic for my diploma thesis in physical volcanology. Since I am infamous among my teachers for my dome work, my supervisors came up with the idea of a classical study of a caldera volcano in El Salvador, connected with an effort to visualize the gathered data in the new immersive form I had been proposing. Returning from fieldwork, it turned out that a sloppy comment I'd made on even building my own dome if the need arose became increasingly serious: there was no dome around where I could easily carry out my research as I wished.

Dome Construction

Obviously, a budget was nonexistent, as was as the intention of my institution to invest in a large facility at the whim of a master's student. A hard shell design had to be ruled out for its complex manufacture process. Support by air pressure offered an alternative.

There were a number of further criteria: the dome was to be mobile and lightweight, yet weatherproof, sturdy, and flexible to accommodate a number of different video and audio setups. There should be a possibility for changing the canvas to try different levels of reflectivity as well as rear projection capabili-



Left: Test assembly of the support structure. Note the modular foundation ring at the base. Correct dimensions were validated using a theodolite. Right: Rear projection test without the inner canvas. Note the projector (on boxes) and the evacuation nozzle at left. The dome rests on 10 vertical metal struts of 2m length. The projection (one channel active) is calibrated for 180° FoV. All photos by and/or courtesy the author.

ties for inside-out projection.

Astronomers look up, geologists look down. My very personal opinion is that tilted domes are intriguing compared to non-tilted domes, yet the cinematic language we use is still very close to movies. For the sake of making a difference and exploring truly omnidirectional setups, I wanted a hyper-dome of 220° that reached below the horizon. On the other hand, the design should allow the entire dome to be tilted if desired. Just a slight tilt of 10° would thus allow the simulation of a 30° tilted theatre, facilitating show production aimed at several different dome tilts.

This led to the design of a dome of 6 m inner diameter and 220° screen coverage. It was supported by a fourth frequency geodesic hemispheric framework made of PVC tubing with an additional section covering the twenty degrees below the horizon down to a robust foundation ring made of PE tubing. The structure was to be covered by an outer canvas attached airtight to the spring line, along with an inner canvas attached to the spring line from within. By evacuating the space between the two fabrics, one could get a perfectly spherical dome held up by negative pressure. Since the diameter of the outer canvas and the support structure was 30 cm larger than the inner canvas, there was still 15 cm of space to fit an array of small speakers between the two hulls. While positive pressure would not have required the complex geodesic structure, it would have demanded airtight walls or sitting on the floor.

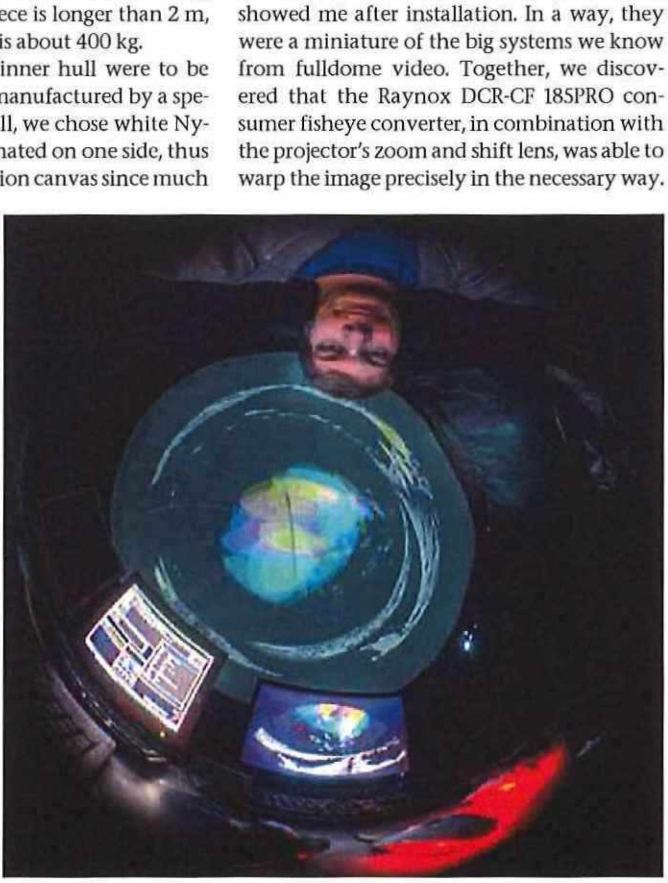
I found a very detailed tutorial on geodesic structures on the internet, kindly provided by a man who builds them for the Burning Man Festival.[1] I essentially just followed the instructions and fabricated the entire structure during one week in our garage, not knowing if my work was precise enough to fit together. It was. PVC proved to be an inexpensive, robust, and easy-to-manufacture material, especially when using a heat fan. The whole structure is made of 300 struts of seven different lengths, which are easily attached to each other using screws and bolts. No piece is longer than 2 m, and the overall weight is about 400 kg.

Both the outer and inner hull were to be made from fabric and manufactured by a specialist. For the outer hull, we chose white Nylon, 220g/m², and laminated on one side, thus becoming a rear projection canvas since much of this article would still be readable if stuck behind it. The inner canvas (the actual projection dome) is a special polyester black-out canvas coated with cotton. From behind, the inner canvas has lashes to attach it to the geodesic structure; therefore, it will not fall down on the audience and the equipment in case the negative pressure fails.

Projection Equipment

By sheer chance, I had learned what the edge blends of a single warped channel for a Sony SXRD system looked like. (It is obvious that there is a reflection in the lenses; just walk up to them during a demo.) This system had great appeal to me, as it kept the center of the dome clear of any equipment and still only used two channels.

At that time, a friend of mine had just ordered four Sony VPL-VW 50 full-HD projectors with SXRD chips for teaching, which he showed me after installation. In a way, they were a miniature of the big systems we know from fulldome video. Together, we discovered that the Raynox DCR-CF 185PRO consumer fisheye converter, in combination with the projector's zoom and shift lens, was able to warp the image precisely in the necessary way.



The author during a demo of the isopach simulation on Digistar3 SP2. The gore seams have not yet been sealed, aiding the development of projector alignment setups.

1 www.desertdomes.com


Left: Closeup of a dome master of the isopach animation. Above the grey map of Central America there is a suite of color coded eruptions with their respective approximated eruption column geometries. Right: Geometry model of an outcrop in El Salvador with its reconstructed fault planes (yellow). The camera is on street level, the road has not been modeled. Note advertisement graffiti on the walls.

I borrowed two lenses from friends and two projectors from my preferred hardware dealer.

Since the hangar was not always available, the dome has been set up three times during a period of four months, each time limited to just a few days. Therefore the projector alignment was intentionally never perfected.

Image Generator Software

Parallel to months of dome construction, I had been carrying on with my research and the preparation of data. I was fortunate to gain the support of SCISS AB, which kindly provided me with a copy of Uniview for the sole purpose of my thesis work and possibly the development of data.

Uniview by itself does not warp the image for dome projection, but relies on relay software or graphics hardware to do that. In my case, I chose the OmniMap geocorrection library, which is freely available from the Elumenati[2] website. Even though it assumes the use of a fisheye camera and one can quite extensively manipulate the site and orientation of the projector relative to the dome, it was written with single lens projection in mind and I was told there had not been a dual channel setup.

Nevertheless, I was able to align the system for 180° projection until the only alignment errors were due to the makeshift prototype lens and projector mounts. I am convinced that the alignment would have been perfect with the final adaptors, but this was a test limited to a few days.

Apart from our longtime mutual plans for geoscientific data visualization, the reason for the use of Uniview was its ability to load data in the format of Google's™ Keyhole Markup language (KML), which offered a direct interface to geoscientific software packages such as ArcGis. This led to a very friendly exchange with colleagues at the Denver Museum of Nature and Science, who gave me a jump start into this application.

The other key feature was the ability to stream high resolution map data from World Map Services (such as the server of Google Earth) from various NASA and NOAA institutions. This technology allows browsing large geoscientific datasets or extremely high resolution satellite imagery on a dome and, since it is accessible from the internet, one can share the data with other institutions running desktop or dome applications. The challenge with these services is their complexity: You do not upload anything to the existing servers. If you want to display your own content, you need to run such a server. The software to do that is free on the web.

At this point, I was asked to present my work (and a bit more) to a delegation of the German Research Foundation (DFG) visiting our institution and evaluating our work (that is to say, they were deciding on the continuation of all our jobs). Suddenly, I found myself facing not just my own data, but that of another ten or so scientists, with four weeks over Christmas to produce a 16-minute fulldome data visualization show. The institute even bought the projectors for that.

My luck was perfect when Evans & Sutherland supported my project through an experimental setup of a Digistar3 SP2 system. Not far from where I work is the Mediendom of Kiel at the University of Applied Science. This institution, heavily involved in dome research and teaching itself, entertains a very fruitful cooperation with E&S, and it was in turn through my ties to both of them that I had the chance to tap into this resource. Over the span of three evenings, Markus Schack, head of the Development Department of the Mediendom, installed the system for me, for which I am deeply thankful.

Using the D3 system, we were able to display a whole range of other content pouring out of our department: video footage. In fact, the whole presentation was a single fulldome video since our group did not want to take any risks with the still unfinished real-time version of their data. Although the hardware was somewhat different, the D3 SP2 system behind it ensured a very rapid and standardized workflow that led to the completion of the show just in time. Maybe it would also be useful for an institution that is already equipped with the large Sony System, but needs a comparable downsized alternative for production.

Content

There was a suite of data available. My own research in El Salvador involved the complete geological mapping of the outcrops along about 40km of the Panamerican Highway. Geological maps and elevation data were provided by the Geological Service of El Salvador (SNET).

In addition to traditional techniques, I took multiple high dynamic range (HDR) allskies of all locations, which were later illustrated according to my geological interpretation. Furthermore, I captured all rock walls in mosaics of stereo images, which were later used to reconstruct the entire location as a measurable referenced 3D-model using the software JointMetrix of 3GSM. So far, those models could

2 www.elumenati.com/products/omnimap.html

only be loaded into the dome as an off-line rendering since they are extremely large. That way, it was possible to revisit the sites in the dome and study them at a resolution of only a few cm, later taking remote measurements on a workstation computer.

This demo also saw some successful fulldome 2k live capture that I had shot on one of our research vessels two years before. While this work had initially been done for allsky.de, i.e., for entertainment, it proved to be a great emotional framework for the show and we are currently discussing its scientific impact considering the advances in technology. In a later demo, we included high resolution time lapse of the Hawaiian volcanoes to which the scientists involved also reacted very positively.

My institution, the Leibniz Institute of Marine Sciences IFM-GEOMAR, focuses on marine research and geosciences, comprising a world class suite of submersibles and remotely operated vehicles. Consequently, two complete dive sites at the Central American Trench were processed, including their bathymetry, the vehicle tracks and dynamic video windows of the underwater robot's cameras.[3]

My supervisors provided maps of ash layer abundance[4] (isopachs) for the volcanic systems along the Central American segment of the Ring of Fire. By attributing height information to individual layers of sediment, the geometry of the eruptive ash clouds could be reconstructed and thus their reaction to changing wind directions could be studied using the real-time model.

Geophysical tomography data of the Earth's mantle was exported to 3dsmax from the GOCAD software. These real-time models were incorporated into the above-mentioned models on physical volcanology. Their volumetric nature could only be approximated as transparent planes, yet the visual impression was already convincing.

For all models, their functionality as real time objects could only be validated using the 3dsMax animation window and a 3D mouse. There was no time to port the models to Digistar3, although it could be done and is planned for a later stage.

Conclusion

The overall goal of my dome effort was to validate the usability of domed displays for scientific work. Frustratingly, the scientists I questioned emphasized the use for public outreach over their own benefit, yet the average reactions ranged from positive to enthusiastic. There was a clear consent on the usefulness of illustrated allskies in science and teaching, especially since they are static.

I watched with great happiness as my institution and the Mediendom work closer together, using the Mediendom's 9m dome. The only drawback was the dome cost me more money than I had, therefore I need to sell it. It will be set up during the ADP meeting 6-8 April 2008 at the Mediendom in Kiel. You can read more about the project on www.tomsdome.de, but I strongly advise you to consult your vendor if you have plans for a fulldome system.

Acknowledgements:

I would like to thank the companies Evans & Sutherland and SCISS/Uniview as well as The Elumenati and 3GSM for their generous nonprofit support of this academic undertaking. Practically all of my friends and family were involved in the construction or assembly of the dome.

A big thanks to them, especially to Lars Wind. The Mediendom crew invaluably supported my work in a jump start. I would also like to thank my supervisors, Dr. A. Freundt and Dr. S. Kutterolf, who had the guts to support this project. ☆

Top: Allsky image of a Salvadorian outcrop overlain by stratigraphic and tectonic interpretation based on field notes and image interpretation. Depicted is a sequence of pyroclastic surge deposits. Bottom: Dome master of an ROV dive site. Above the terrain model (grey) there are the tracks of two dives (red, yellow) and the positional data of the species mapped (point cloud). Note that the dataset has multiple layers. The model is surrounded by video windows linked to the tracks (white lines).

3 T. Schleicher, Diploma Thesis; Leibnitz Institut für Meereswissenschaften IFM-GEOMAR, (2006).

4 S. Kutterolf et al., Geochem. Geophys. Geosyst., doi:10.1029/2007GC001631 (in press)