

Scientific 3D Printing

A Work in Progress Report

**Albert Einstein Science Park
GIS Day**

November 20 2013

Peter Löwe (Visiting Scientist)

Jens Klump, Jens Wickert, Marcel Ludwig (GFZ)

Communicating scientific findings

The challenge:

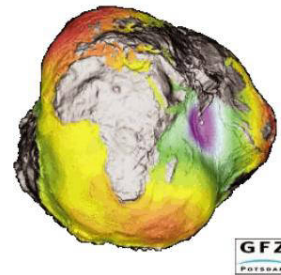
- Visualizing scientific data in one's mind
- Communicating this vision to someone else

The need:

Tangible representation of scientific results.

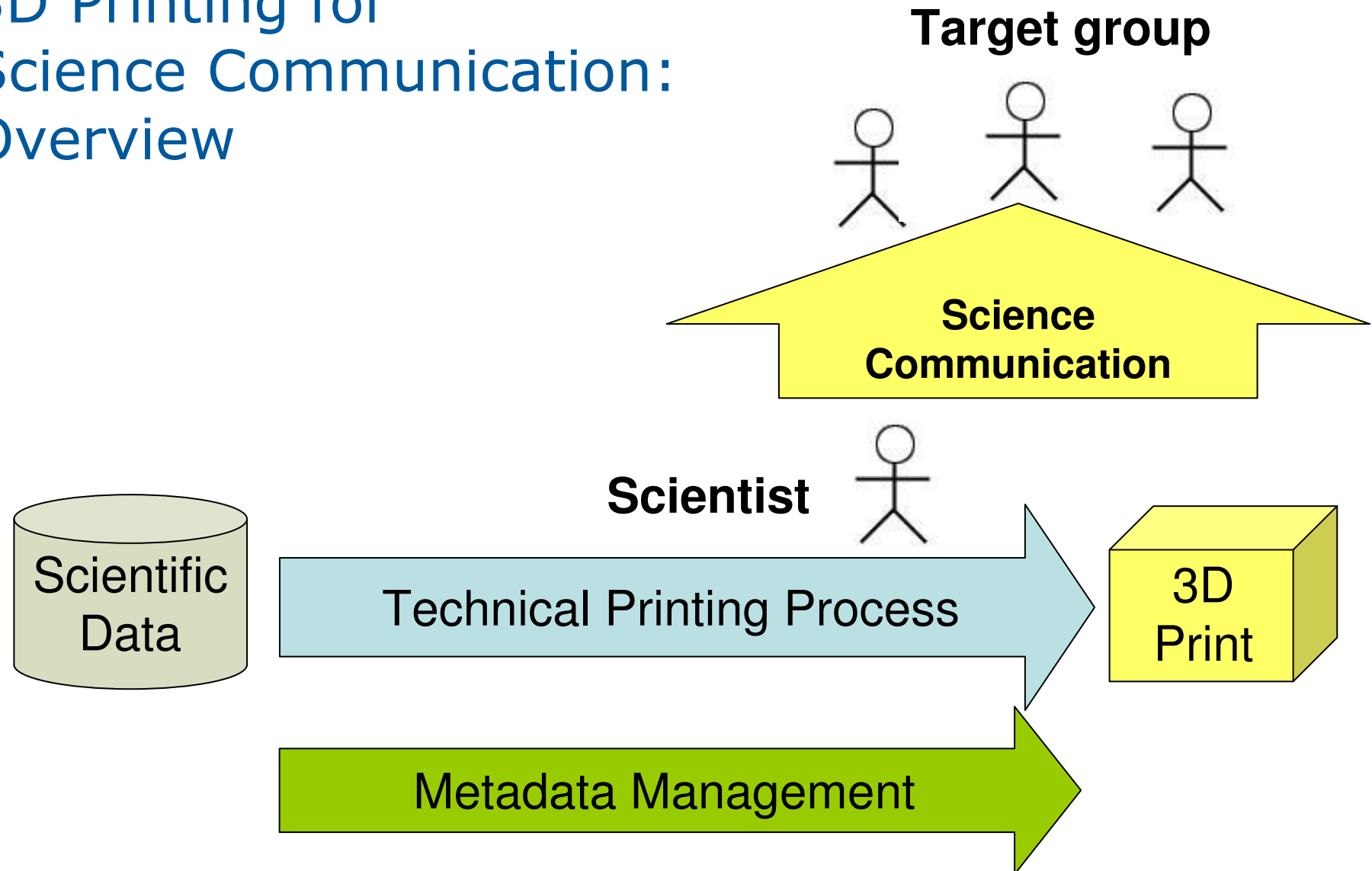


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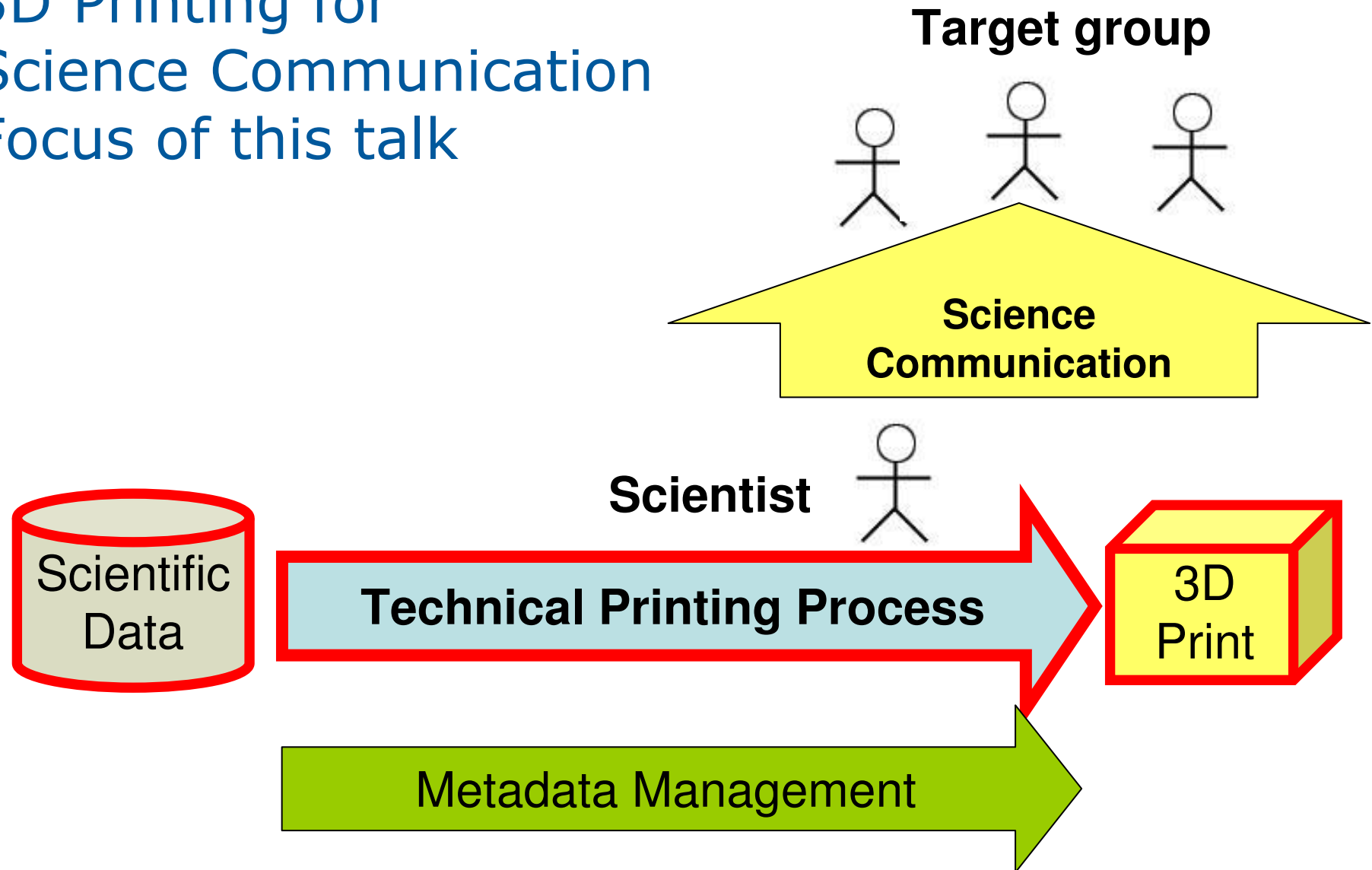


Today

3D Printing for Science Communication: Overview



3D Printing for Science Communication Focus of this talk



Scientific 3D Printing: Application Fields

- **Handpieces** for science communication
 - among scientists
 - towards the general public
- **Showpieces** for exhibitions / trade fairs
- **Condensed information** on content and quality
- **<your application goes here>**

„The Future is here“ (again)

**The potential of „3D printing“ as
featured in the News**

„The Future is here“ (again)



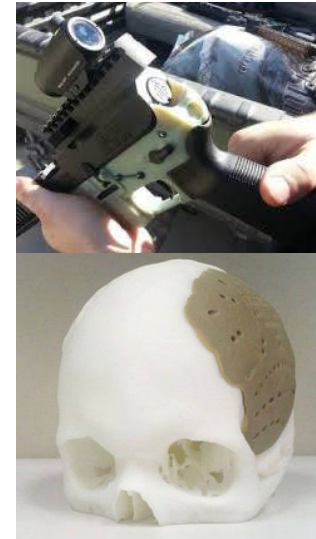
**The potential of „3D printing“ as
featured in the News:**

– Guns !

„The Future is here“ (again)

The potential of „3D printing“ as featured in the News:

- **Guns !**
- **Human body parts !**



„The Future is here“ (again)

The potential of „3D printing“ as featured in the News:

- **Guns !**
- **Human body parts !**
- **Clothes !**



„The Future is here“ (again)

The potential of „3D printing“ as featured in the News:

- **Guns !**
- **Human body parts !**
- **Clothes !**
- **Candy !**



„The Future is here“ (again)

The potential of „3D printing“ as featured in the News:

- **Guns !**
- **Human body parts !**
- **Clothes !**
- **Candy !**
- **Space Exploration !**



Reality Check

THE FUTURE IS HERE



ZX81

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Now Timex brings you a real computer at an unreal price with these sophisticated features:

- Unique "one-touch" entry of key words like RUN, LIST, PRINT eliminates tiresome typing.
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*Suggested retail price. © Timex Computer Corporation, 1982.

1983:
ZX81
Homecomputer
(1Kb RAM !)

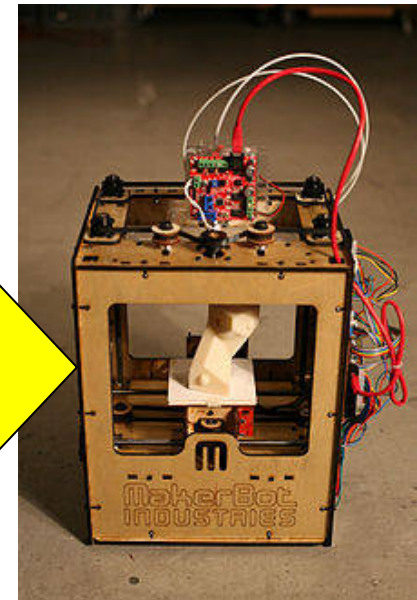
Reality Check – 3D Printing

- Since 1987: Growing use in the manufacturing industry
- Mid 2000s: Low cost printers reach the mainstream



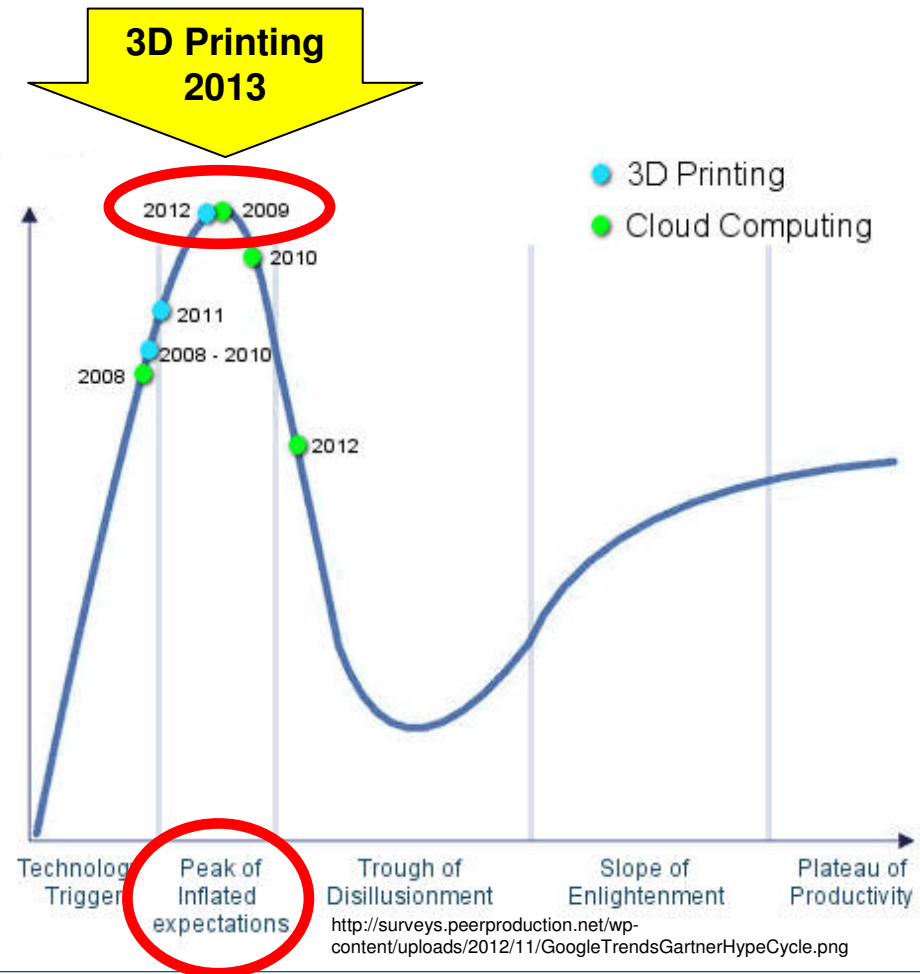
1983:
ZX81
Homecomputer
(1Kb RAM !)

2013:
MakerBot
3D Printer
(1 color!)

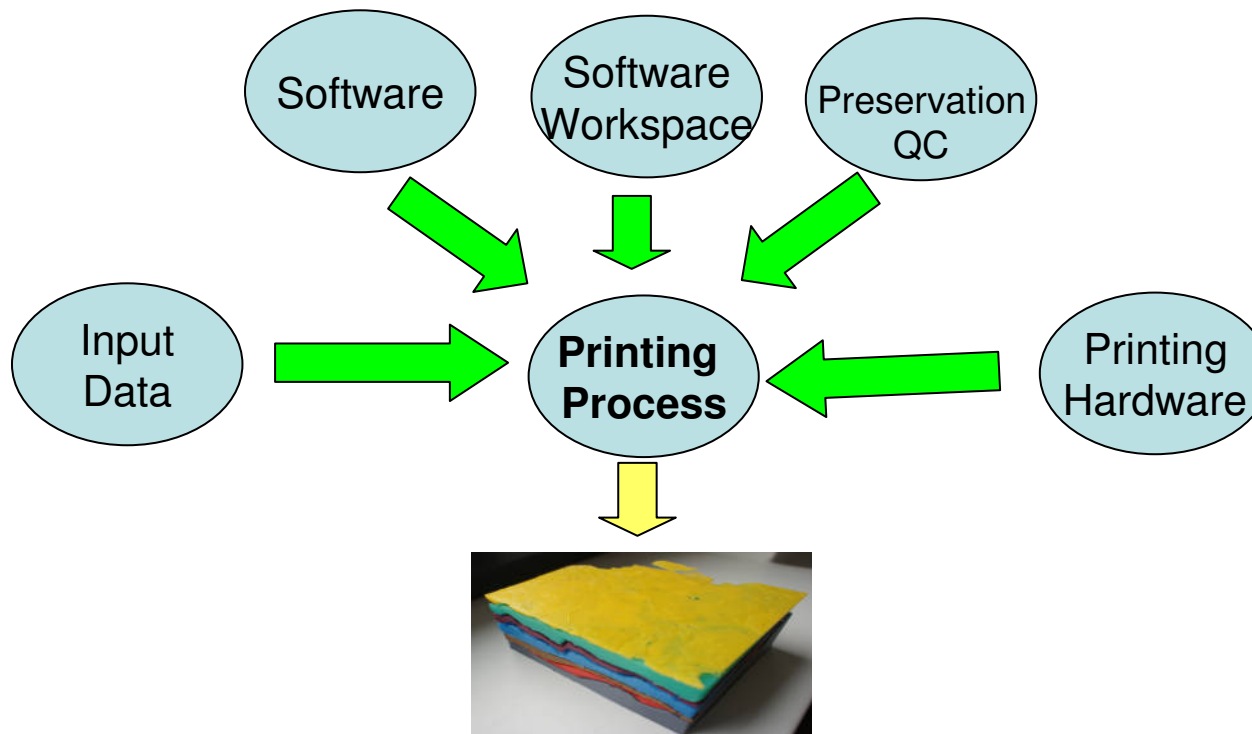


To plot a hype

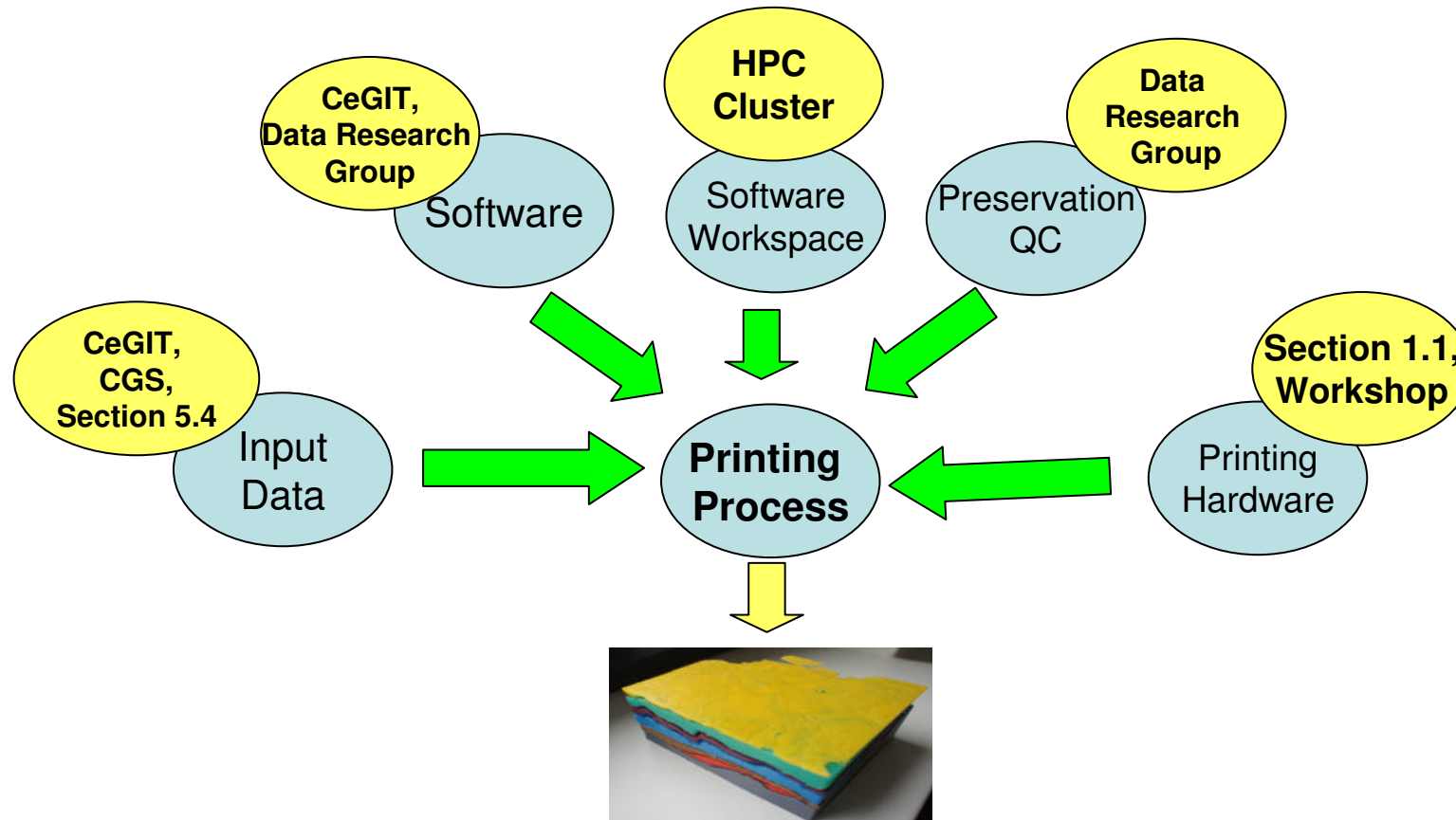
- The introduction of new technologies can be described by a graph.



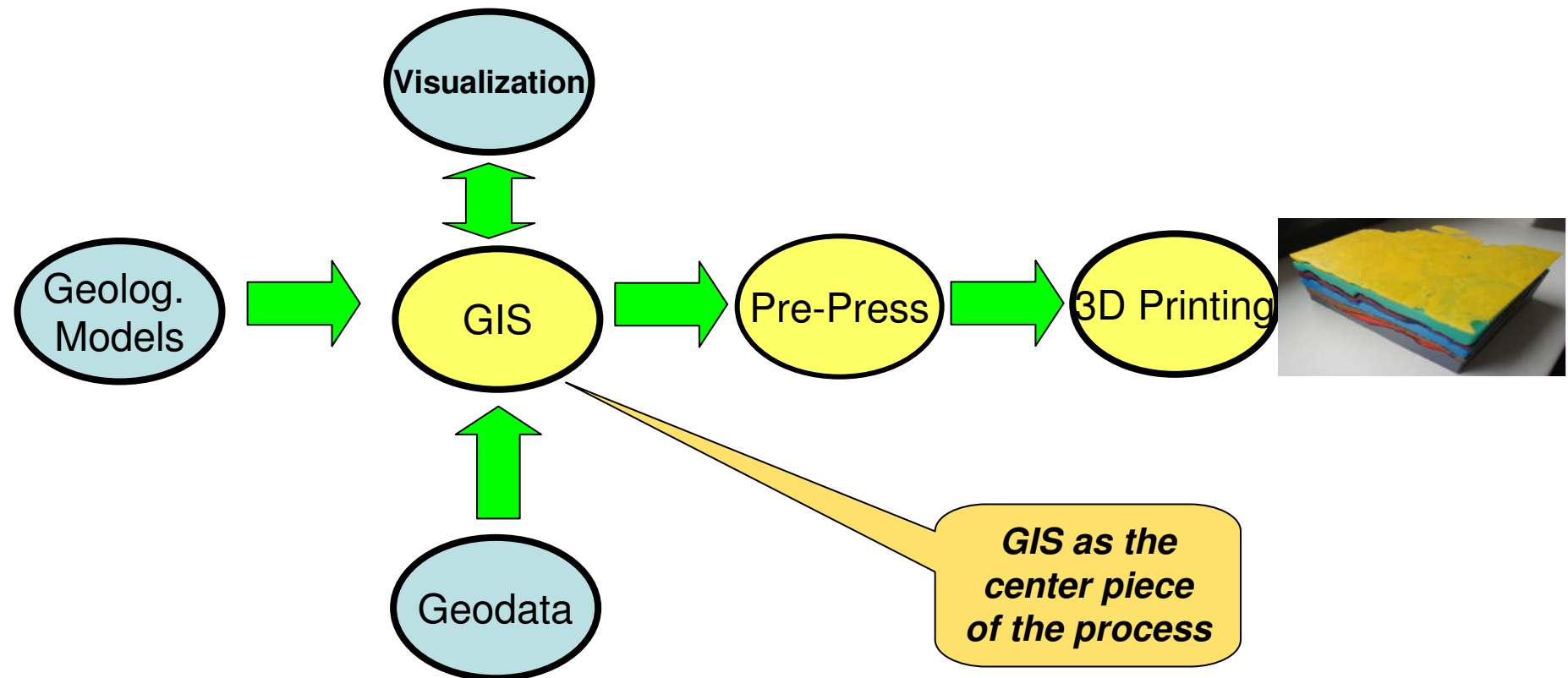
Overview: Tasks and Stakeholders



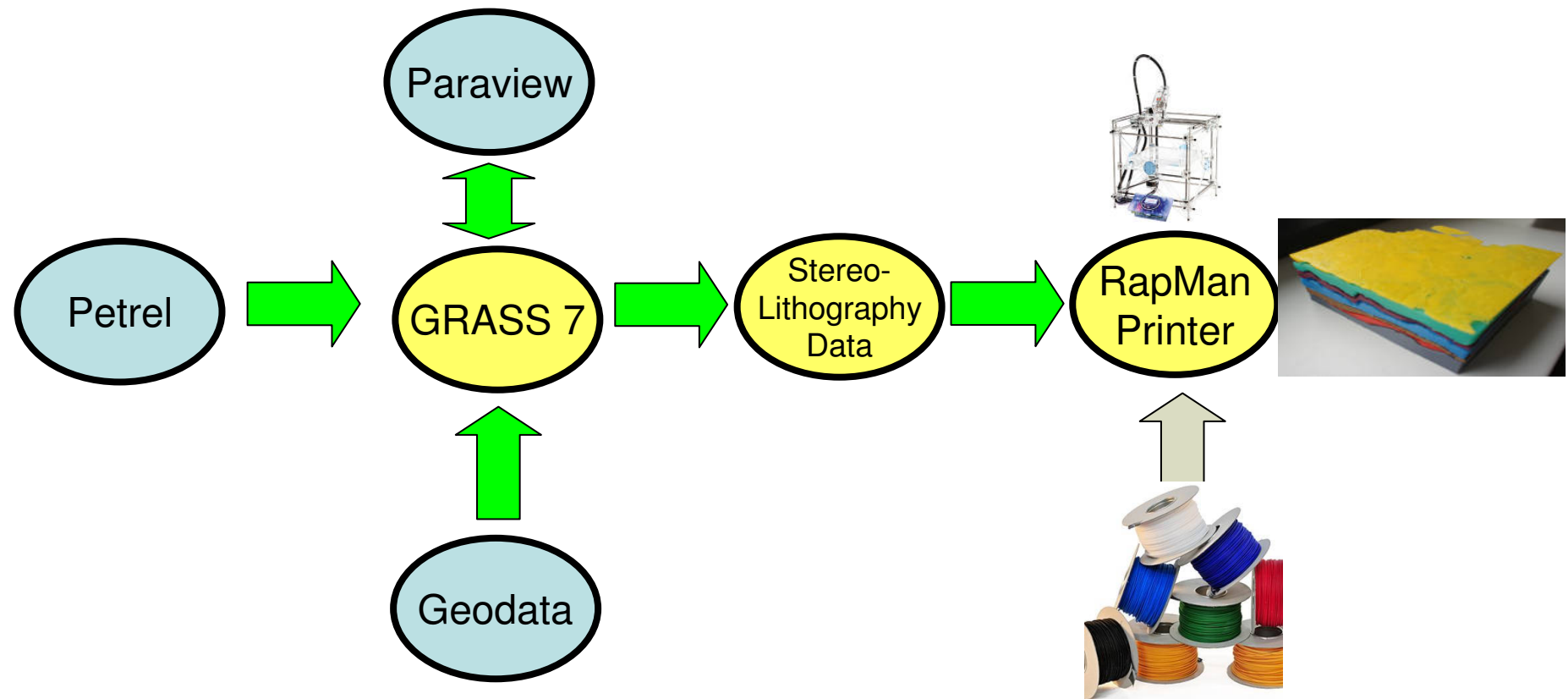
Tasks and Stakeholders Involved Parties at GFZ



Process Overview: From model to printout



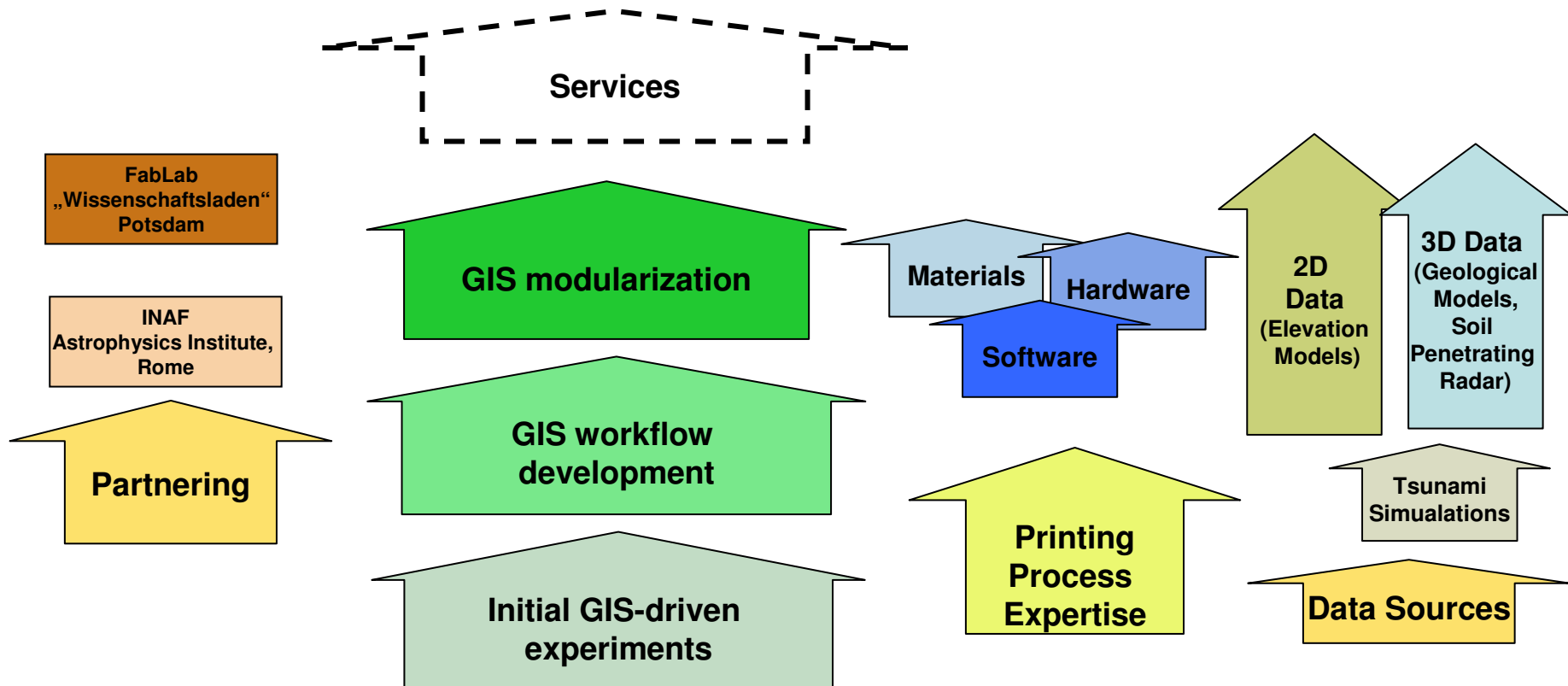
Processing: Software Tools and Formats



Current implementation @ GFZ

- Free and Open Source (FOSS) GIS Software GRASS GIS 7.0
 - **Full support for 3D volume data (volumes)**
 - **Temporal Algebra for 2D and 3D**
 - **FOSS Software can be accessed and extended on all levels. Quickly.**
- Available on the GFZ High Performance Cluster (HPC)
 - **Large file space, large memory,**
 - **Significant parallel processing power**
 - **Scales well**
- Why not ESRI ArcGIS ?
 - **Doesn't run on the Cluster**
 - **Closed source: No quick in-depth tweaking, lacking developer feedback**

Task and Status Overview

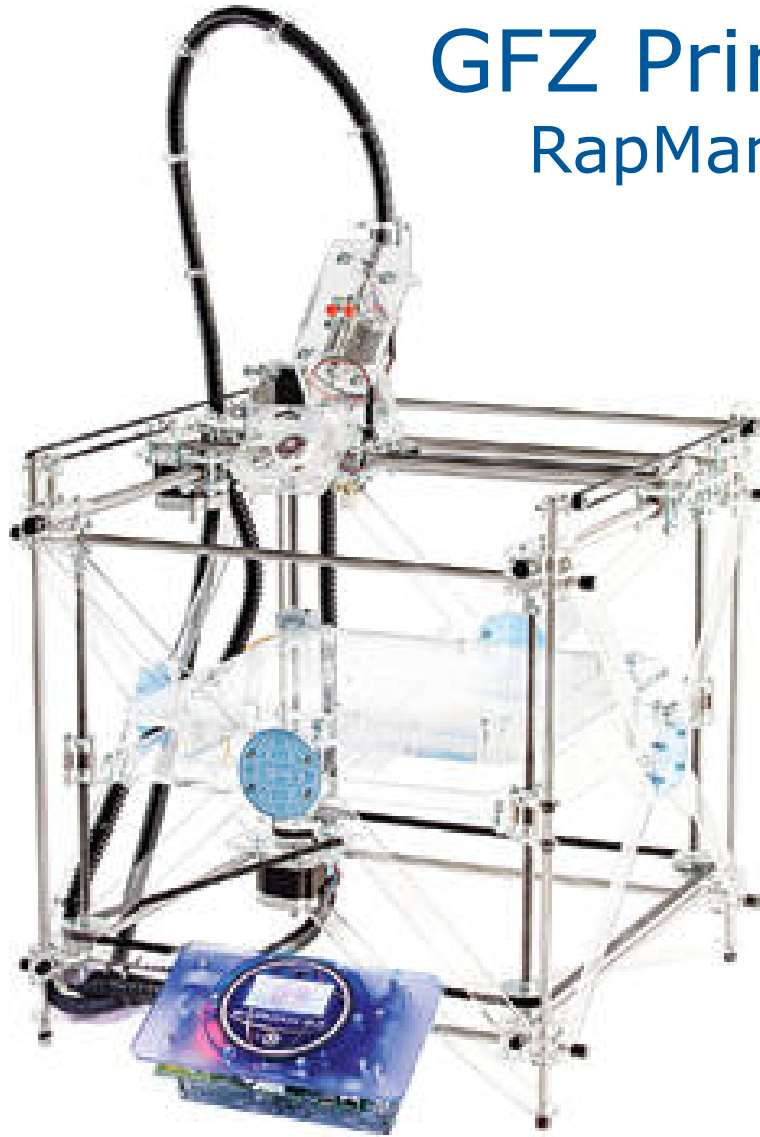


Workflow: Recent advances

- **Petrel data import (volumes and faults)**
- **Improved handling of geologic faults**
- **Improved export to prepress formats**
- **Workflow modularization and simplification**

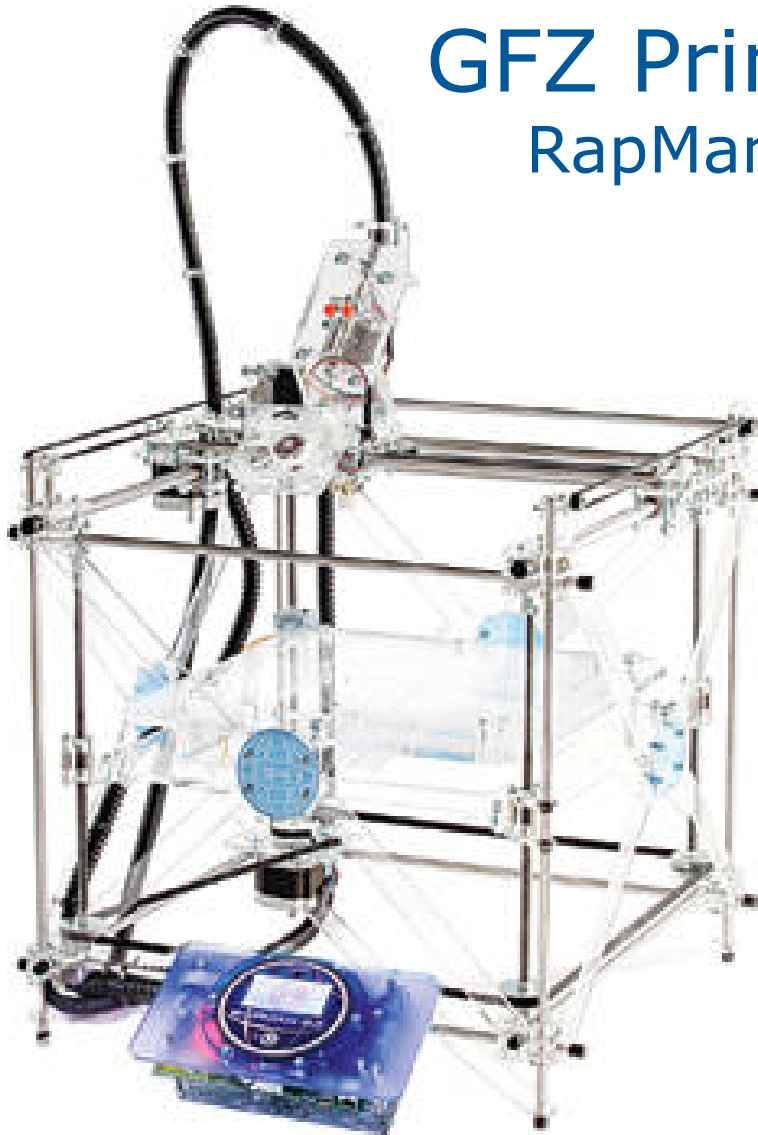
GFZ Printer Hardware

RapMan 3.2 3D Printer



GFZ Printer Hardware

RapMan 3.2 3D Printer



RapMan 3.2: Reality Check



RapMan 3.2: Reality Check



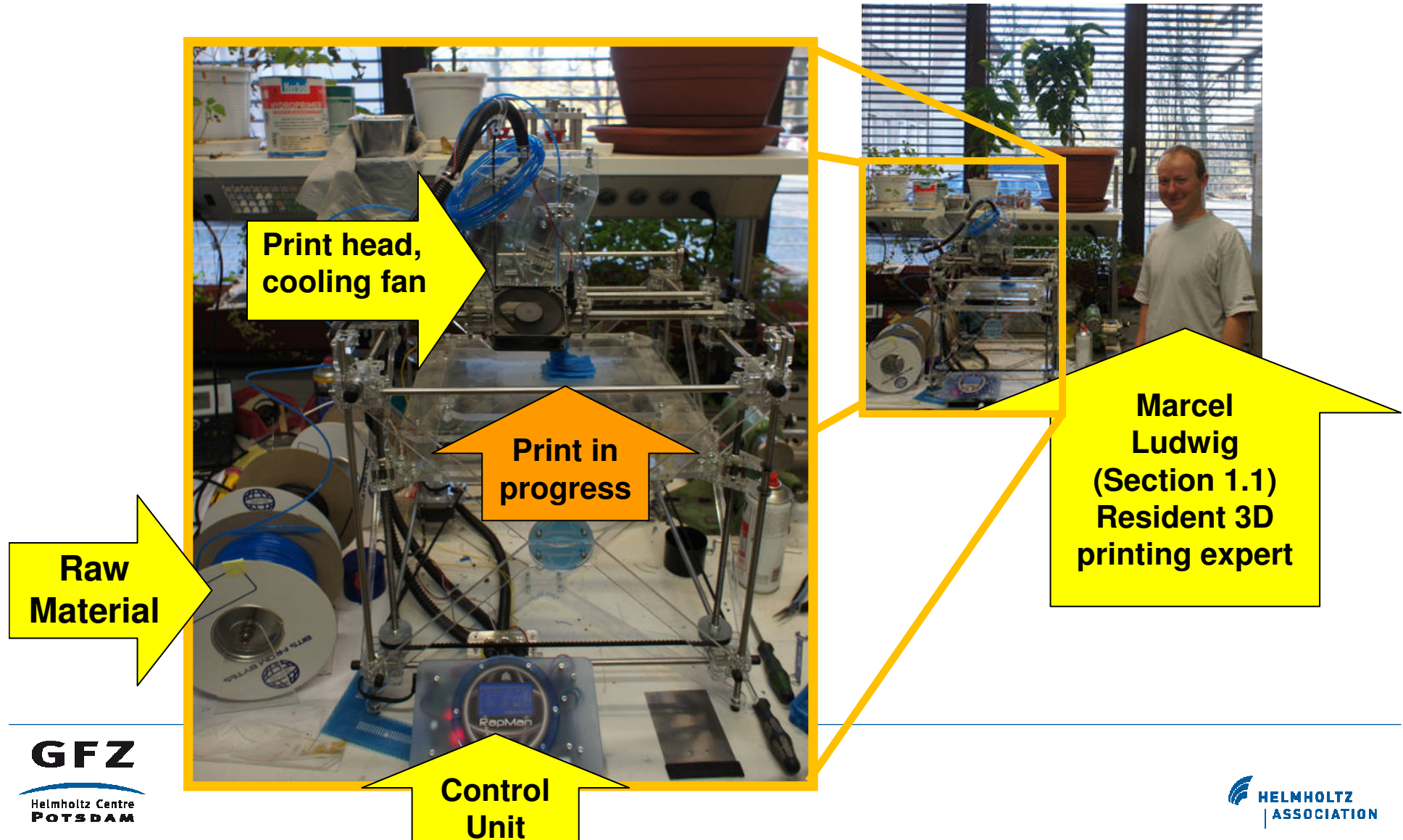
**Marcel
Ludwig
(Section 1.1)
Resident 3D
printing expert**

RapMan 3.2: Reality Check

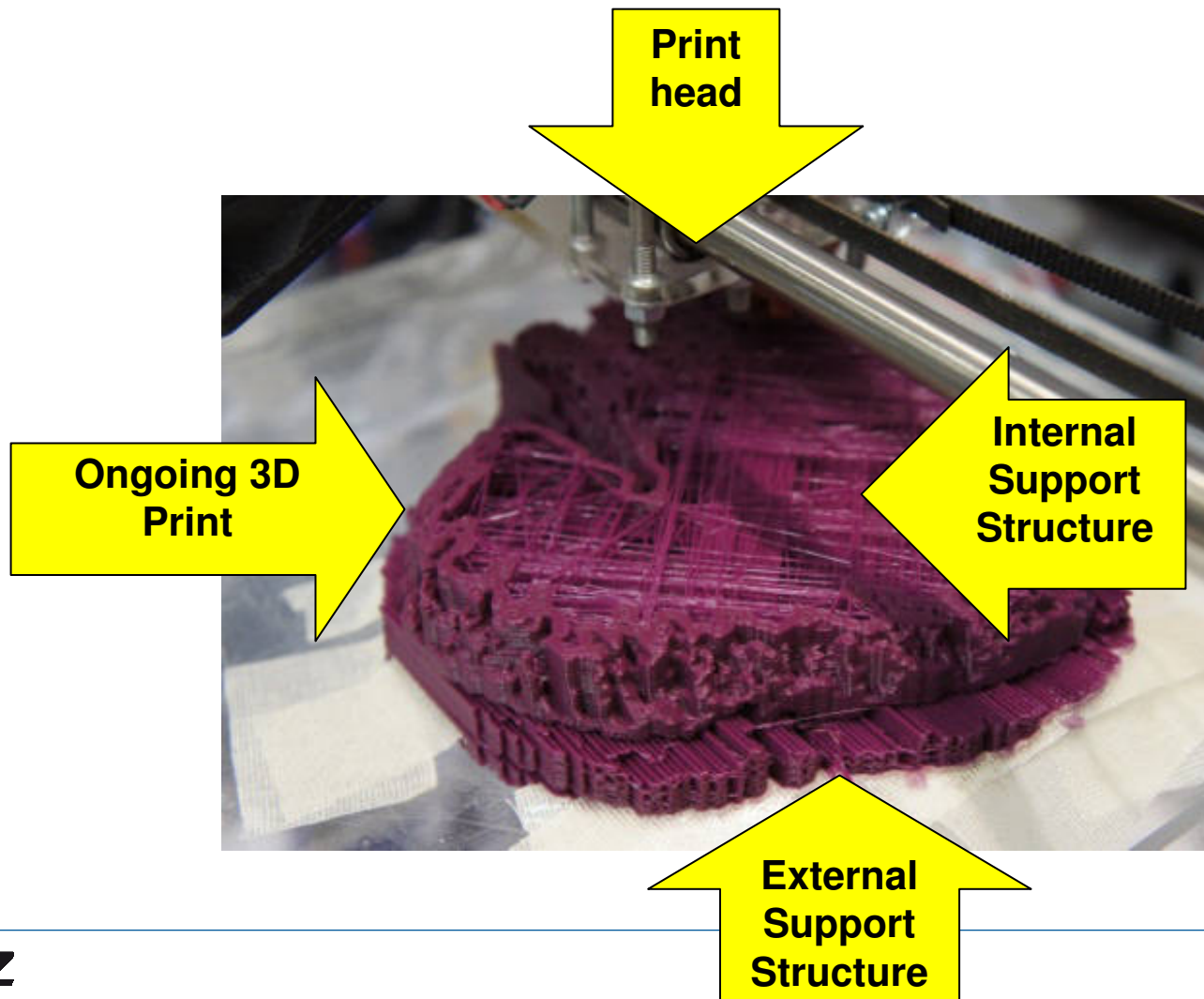


**Marcel
Ludwig
(Section 1.1)
Resident 3D
printing expert**

RapMan 3.2: Reality Check



Close-Up: Actual Printing

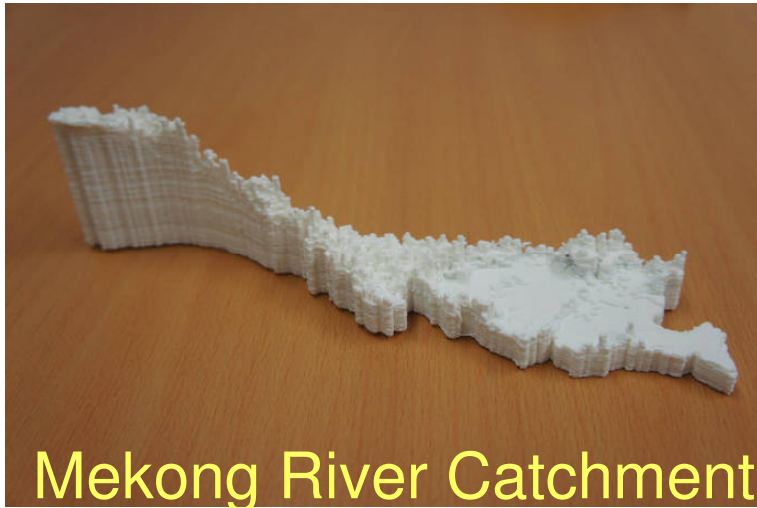


Application Examples

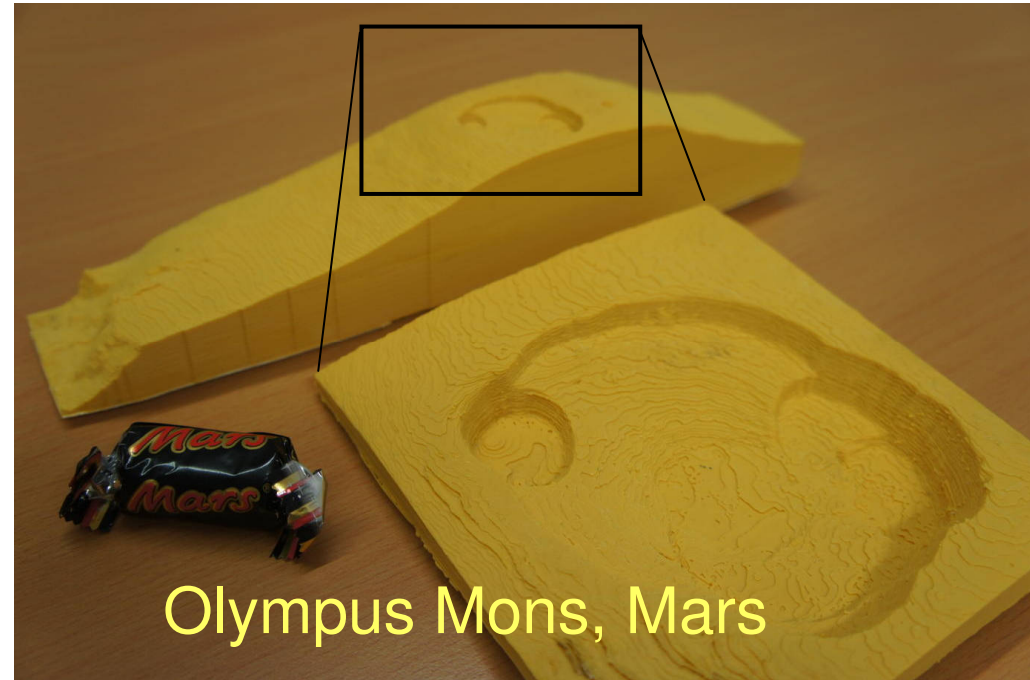
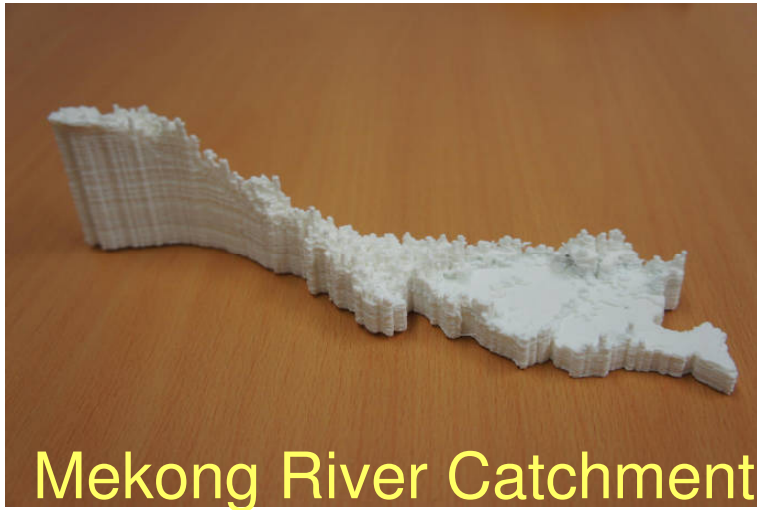
Elevation Models



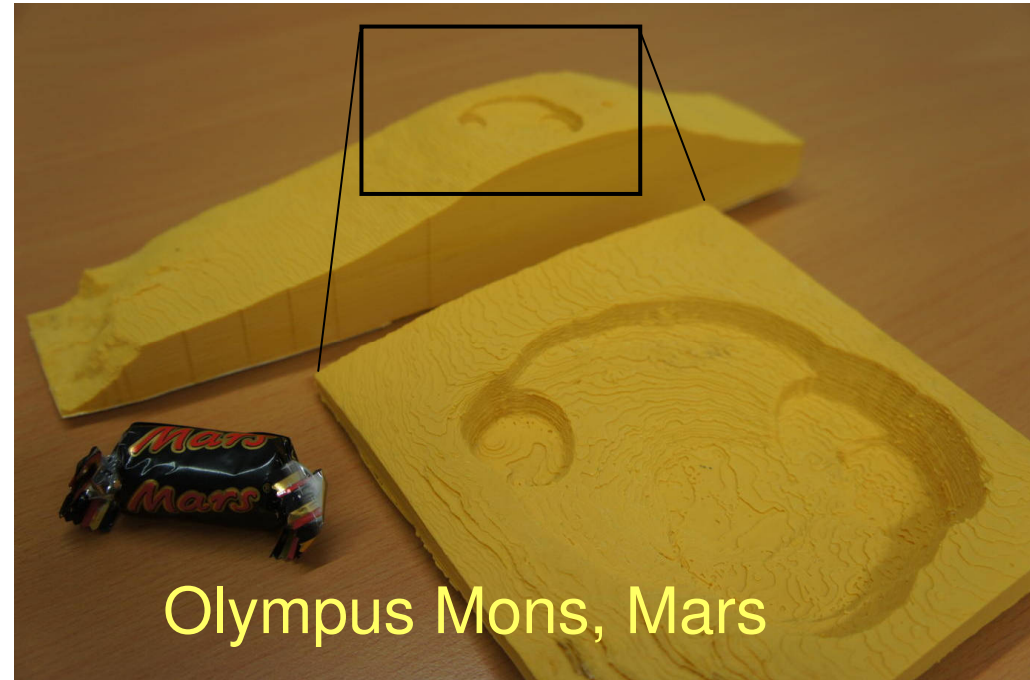
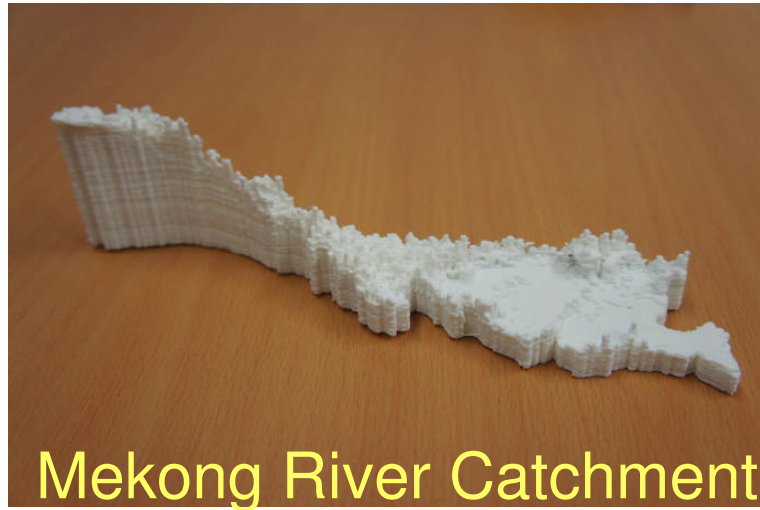
More Elevation Models



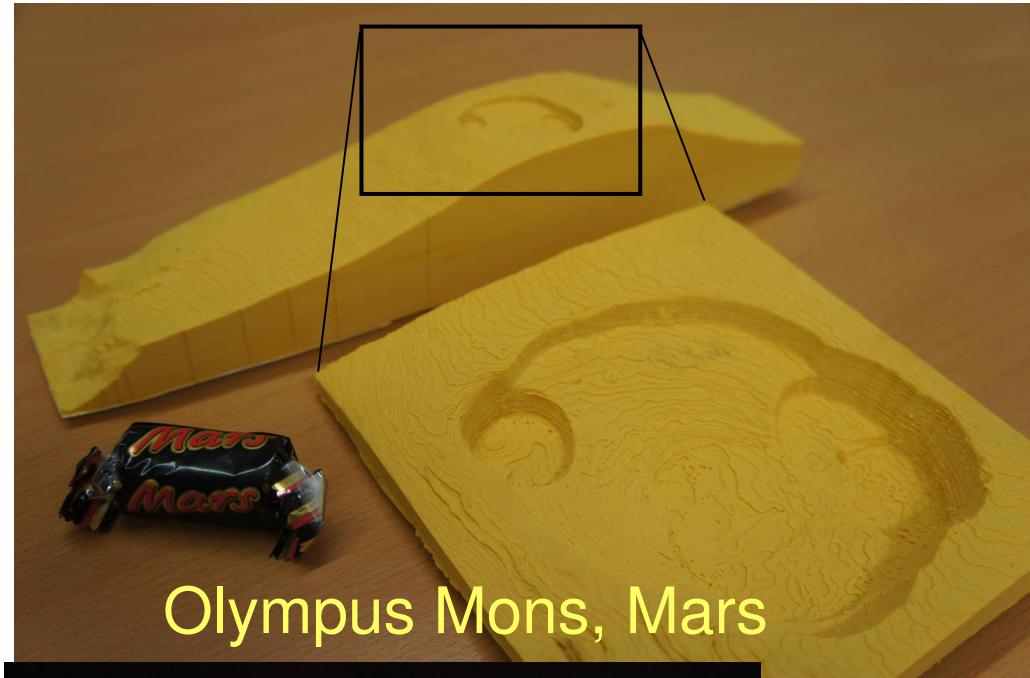
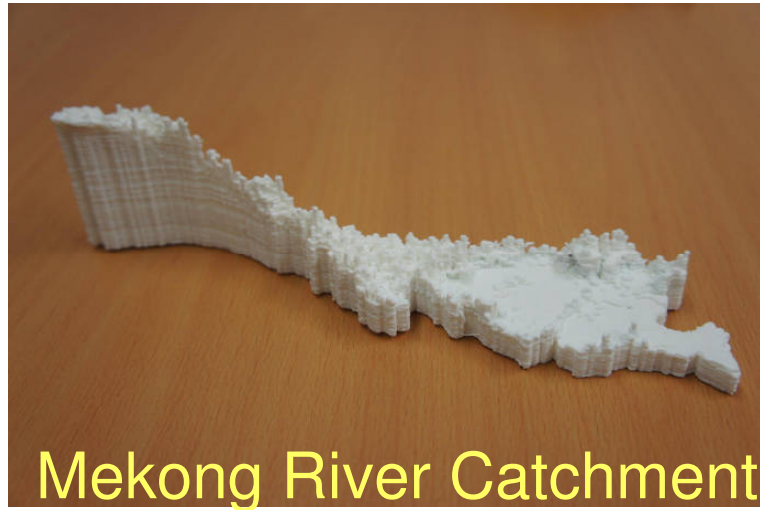
More Elevation Models



More Elevation Models



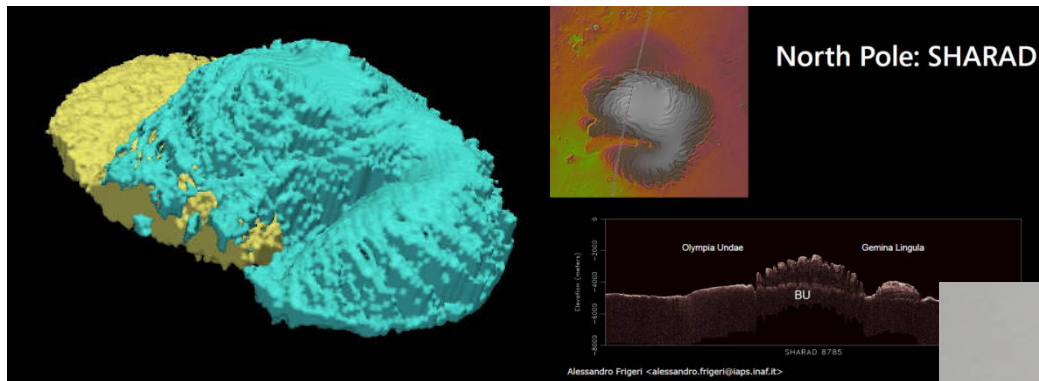
More Elevation Models



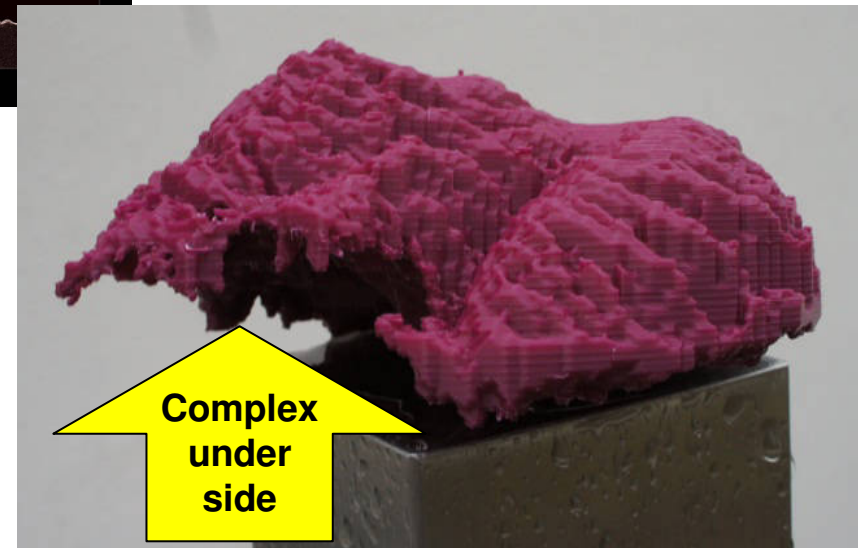
Globes



Single 3D Volume: Mars North Polar Cap



- Ground penetrating Radar from orbit
- „Handpiece“ for communication among scientists and data quality assessment.



Stack of 3D Bodies (Geology)

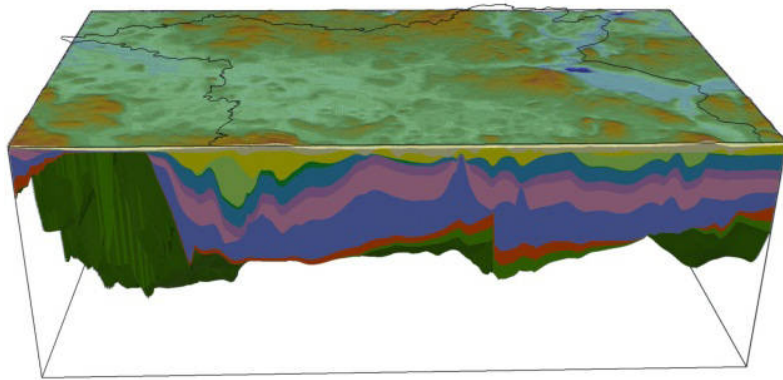
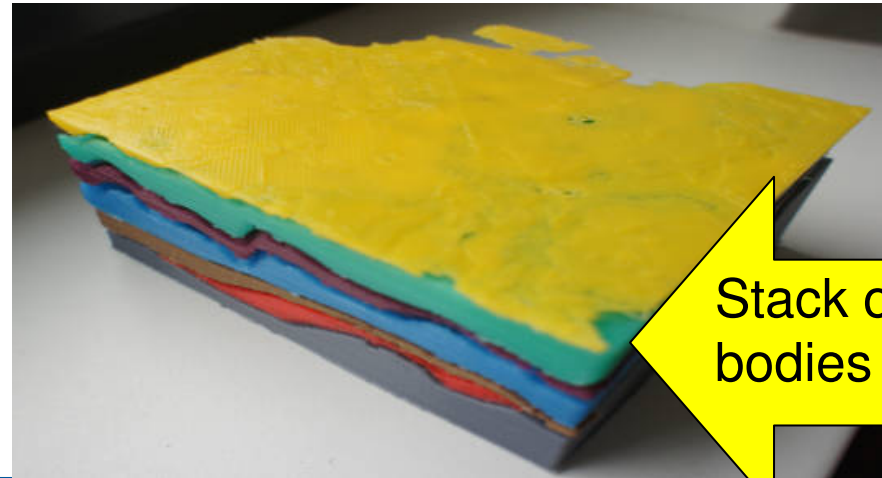


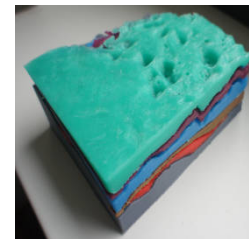
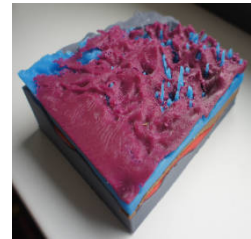
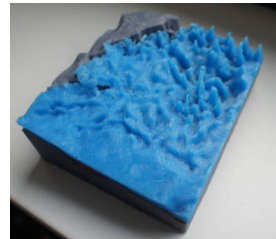
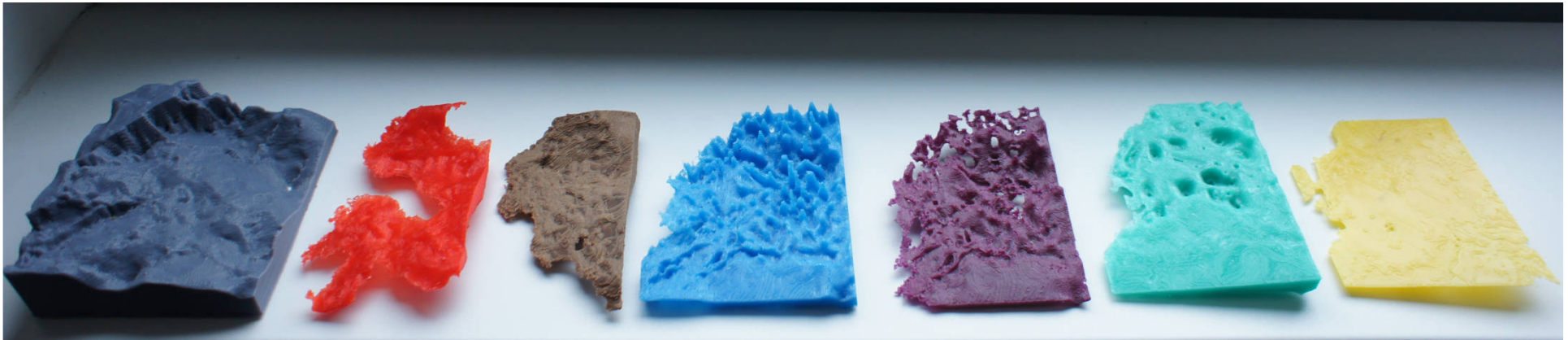
Image: GFZ Section 4.4

Underground model of north-eastern Germany



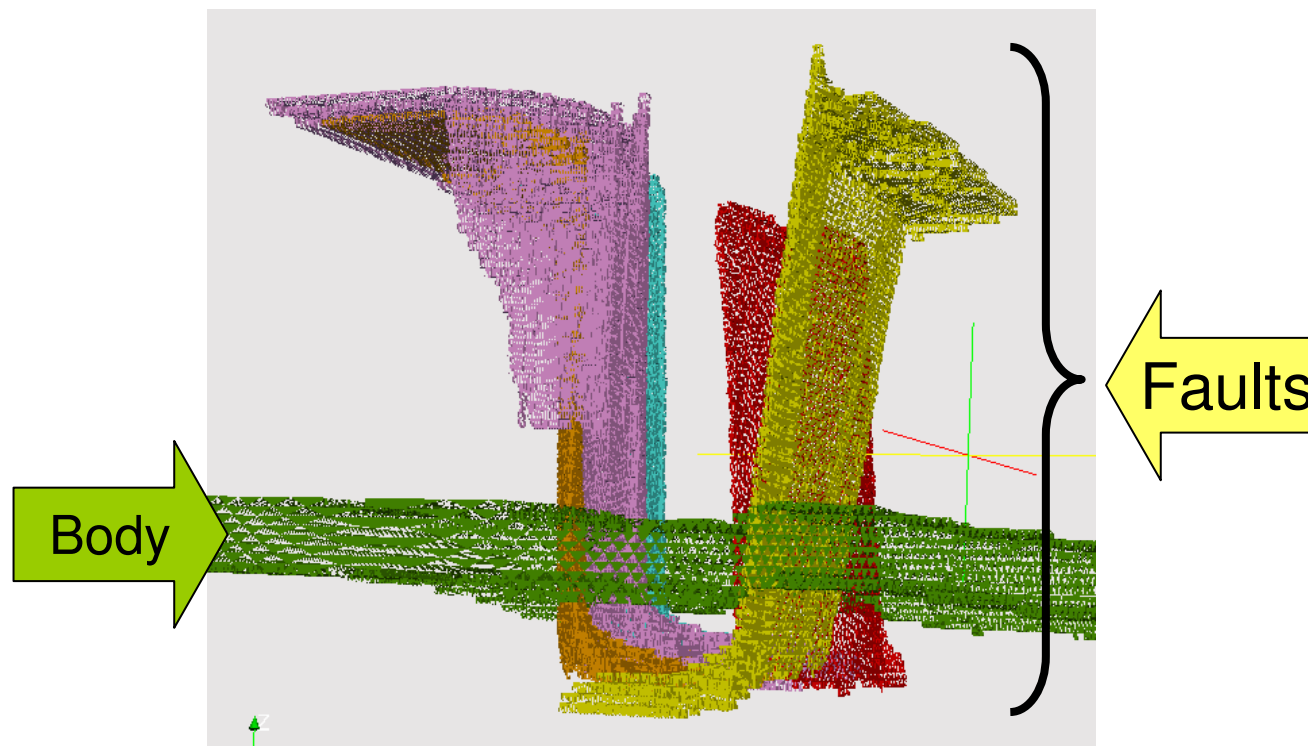
Stack of 3D bodies

3D Volume Stack Details

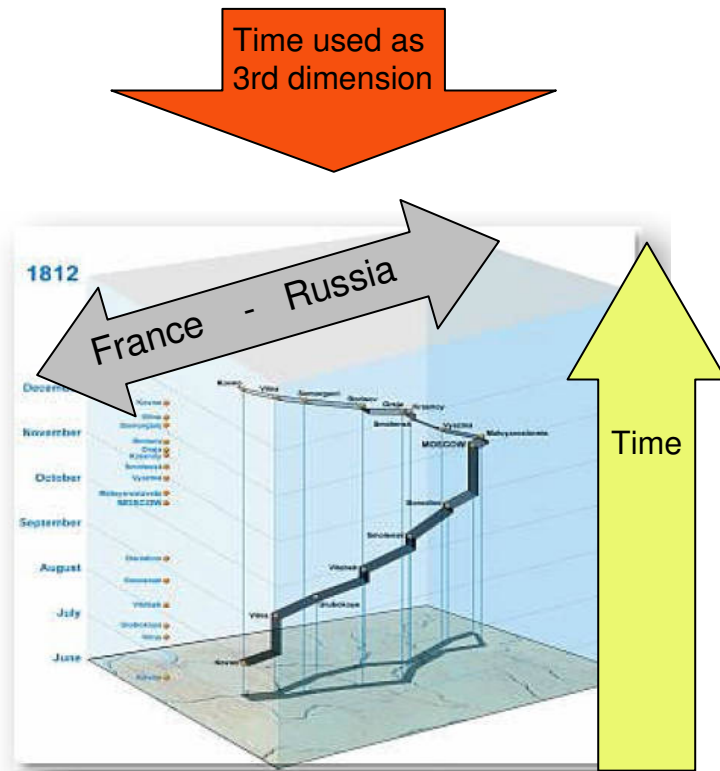


Geological Fault Modelling

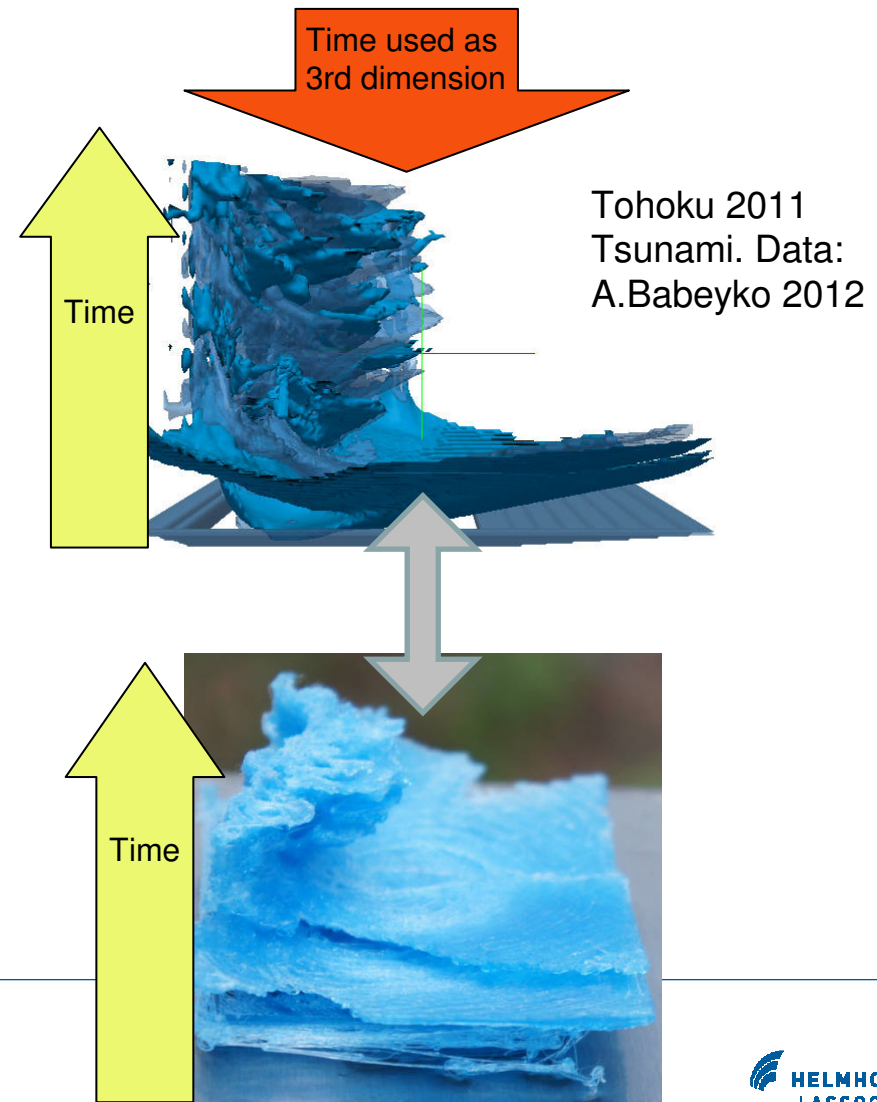
- Separation of geologic volumes along complex faults



Space Time Cubes: Tsunami Propagation

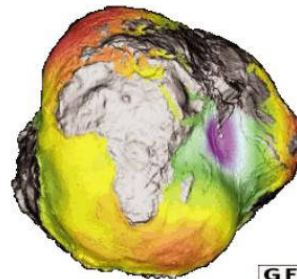


Minard's map of 1869 in the STC, Kraak, 2003



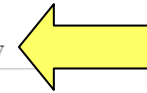
The road ahead

- Additional input data sources
- Workflow improvement
- Intellectual property rights and copyrights
- Archiving of scientific 3D prints
- Improved printer hardware



Main

Open Seismic Repository



Free and public data sets are available for download below. We are [looking for more surveys](#) to make available.

Download Free Seismic Surveys [Torrents]

- [Netherlands Offshore F3 Block Complete 4 GB](#)
Data Summary: 3D Seismic Data, Acoustic Impedance, Wells, Horizons
- [Netherlands Offshore F3 Block Seismic Only 494 MB](#)
Data Summary: 3D Seismic Data, Wells, Horizons
- [Laurentian Basin Canada Complete 2 GB](#)
Data Summary: 2D Data (29 lines)
- [USGS Central Alaska Seismic Only 264 MB](#)
Data Summary: 2D Data (17 lines)
- [Penobscot 3D Survey \(Complete Pre-stack data is also available\)](#)
Data Summary: 3D Seismic data, Prestack 3D data, Wells, Horizons
- [Blake Ridge Hydrates 3D 914 MB](#)
Data summary: 3D PSTM volume offshore South Carolina with gas hydrates

Main

Netherlands Offshore F3 Block - Complete



[Download The 'stacking velocity function' for time-depth conversion exercise!](#)
Right click on the link and Save the link as *Velocity_functions.txt*

General

Country: The Netherlands
Location: Offshore, North Sea
Block: F3
Coordinates: N 54°52'0.86" / E 4°48'47.07 [view in Google Earth](#)
Year: 1987
Data Summary: 3D Seismic Data, Acoustic Impedance, Wells, Horizons
Size: 9.15 GB (uncompressed), 5.71 GB (download)
License:

Contributor



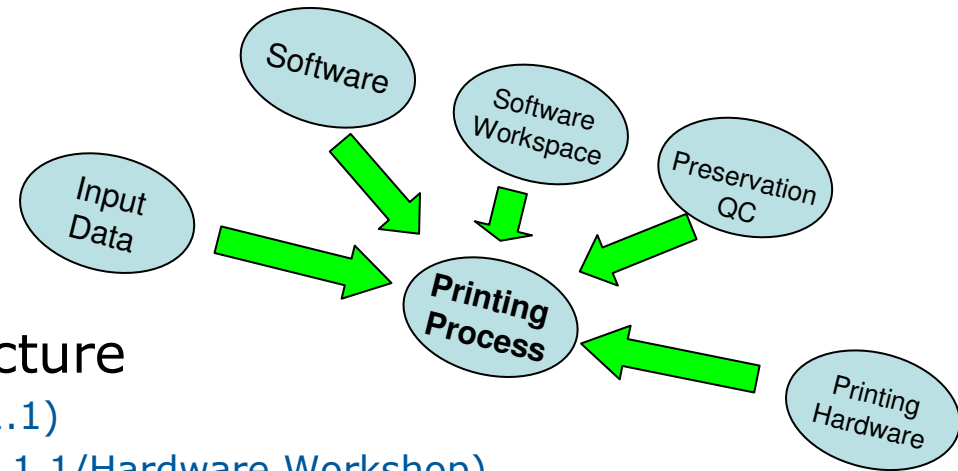
Company: dGB Earth Sciences B.V.
Website: www.dGBes.com
Company: TNO
Website: <http://www.tno.nl>

Scientific 3D Printing at AGU 2013

IN41B-1606

*„An open source workflow for 3D printouts of
scientific data volumes“
(Poster presentation)*

Thanks you supporters !



- Hardware Infrastructure
 - Jens Wickert (Section 1.1)
 - Marcel Ludwig (Section 1.1/Hardware Workshop)
- High Performance Computing Environment:
 - Jan Thaler (CeGIT)
 - Marina Köhler (Computation Centre / HPC Cluster)
- Data Research
 - Jens Klump (CeGIT / Data Research Group)
- Science Data
 - Joachim Wächter, Dorit Kerschke (CeGIT)
 - Tanja Kollersberger (CGS)
 - Section 5.4 (Hydrology)
 - Alessandro Frigeri (INAF, Rome)

Thank you.

Have a great GIS Day 2013 !

