

Generating 3D models of Shukhov towers by laser-scanning and UAV photogrammetry

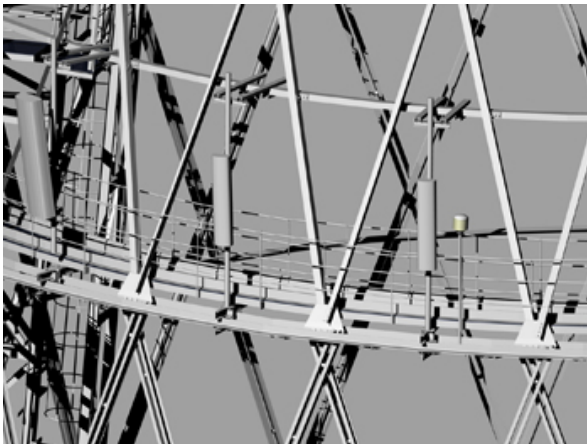
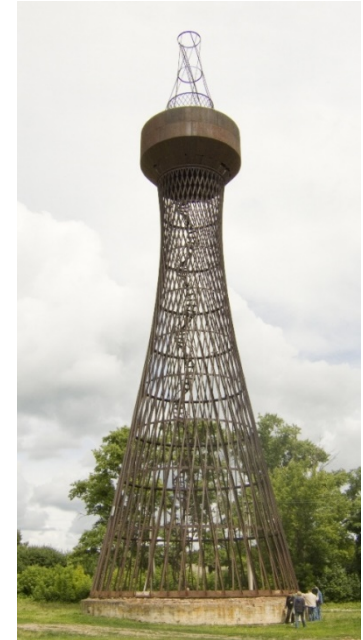
Prof. em. Dr. Armin Gruen

Chair of Information Architecture, ETH Zurich

Singapore-ETH Centre, Future Cities Laboratory, Singapore

agruen@geod.baug.ethz.ch

1. Introduction
2. Schabolovskaya, Polibino
3. Conclusions, perspectives



Advantages of UAVs

- Flexibility in sensor design and integration, data acquisition and flight pattern (navigation, flying height)
- Use in high-risk situations
- Flight close to object
- Production of vertical, oblique and horizontal images
- Fast data processing (download, on-line, real-time)
- Inexpensive platform (manufacturing, operation)
- High educational value



Disadvantages of UAVs

- + Weather conditions
- + Weight restrictions (small sensors)
- + Local operation ~1-3 km
- + Limited absolute flying height (helis: lack of uplift and oxygen)
- + Professional training and attendance for helicopter pilot
- + Safety issues
- + Cannot cope with obstacles (avoidance of collisions)
- + Payload limit in Switzerland < 30 kg
- + Other legal regulations (permissions from terrain/object owners, flight control authorities, etc.)
- + Technology (hard- and system software) is not mature enough



Schabolovskaya Tower (Shukhov)

Built 1919-1922

Radio station for international connections of the young Soviet state

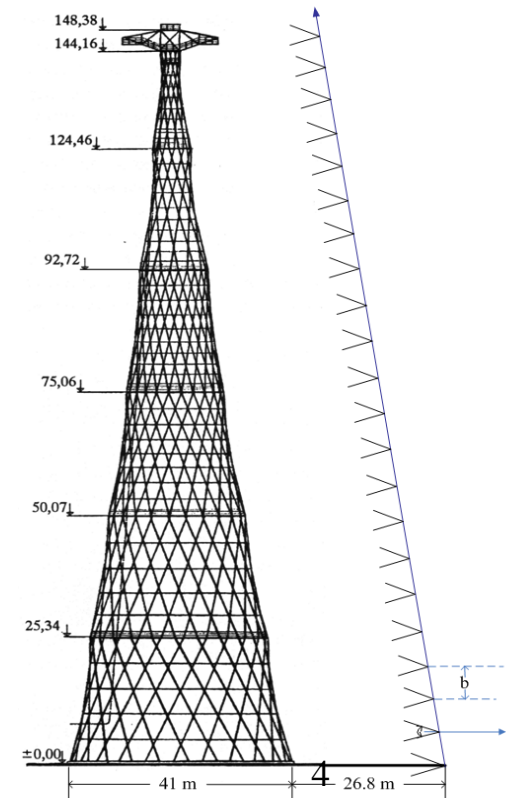
First version: 350 m high, with Lenin's permission

After 1939: TV antennas

Today: Belongs to Russian State TV

Restricted accessibility

Transmitters for mobile communication



Vladimir G. Shuhkov (1853-1939)

Engineer, architect, inventor

Lattice towers

Iron, steel, hyperboloids

20 of more than 200 towers survived

+ Polibino, 1896

+ Schabolovskaya, 1921-22

+ Nigres, 1927

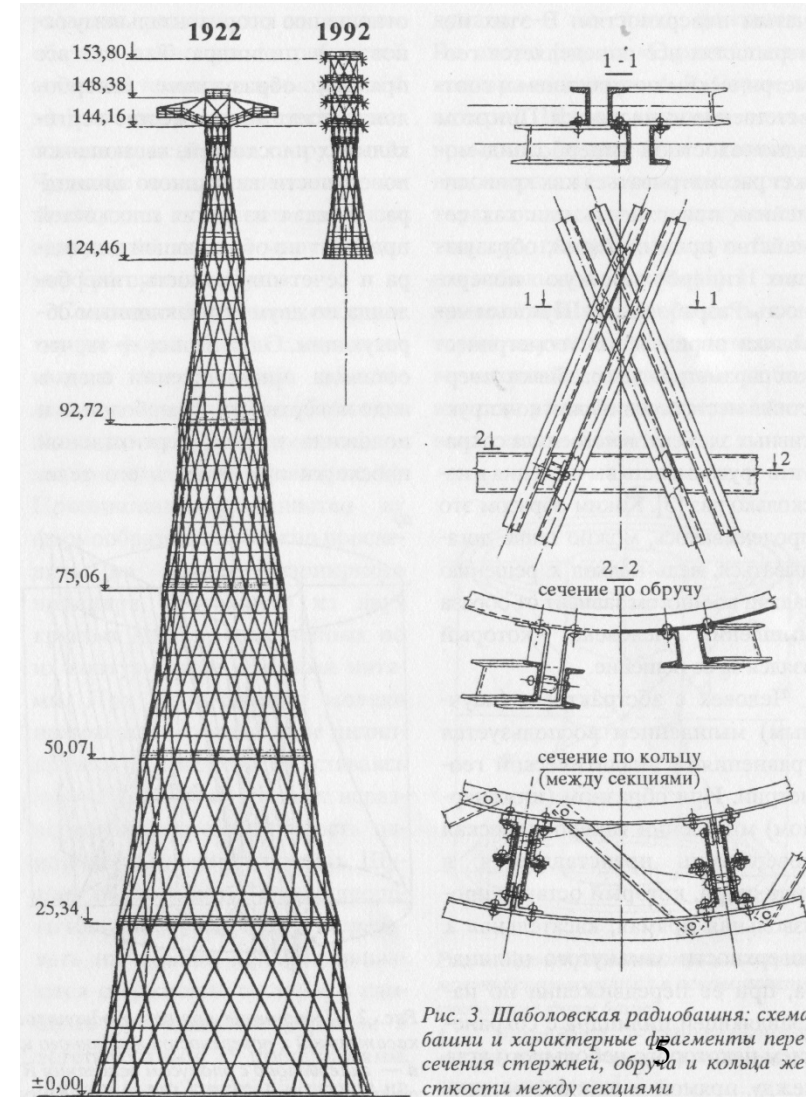
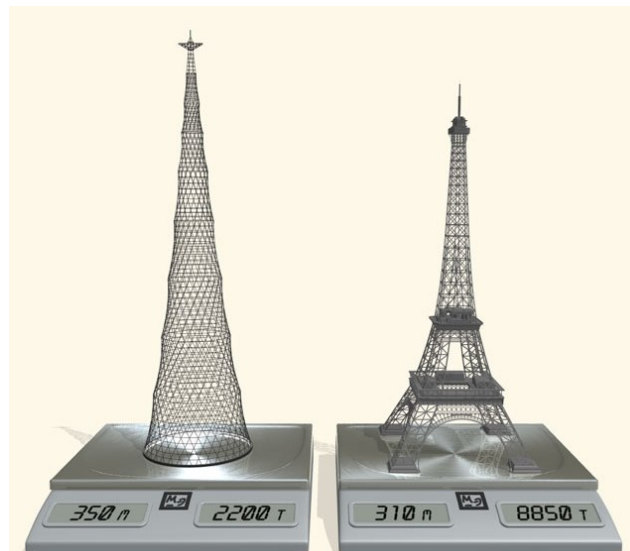
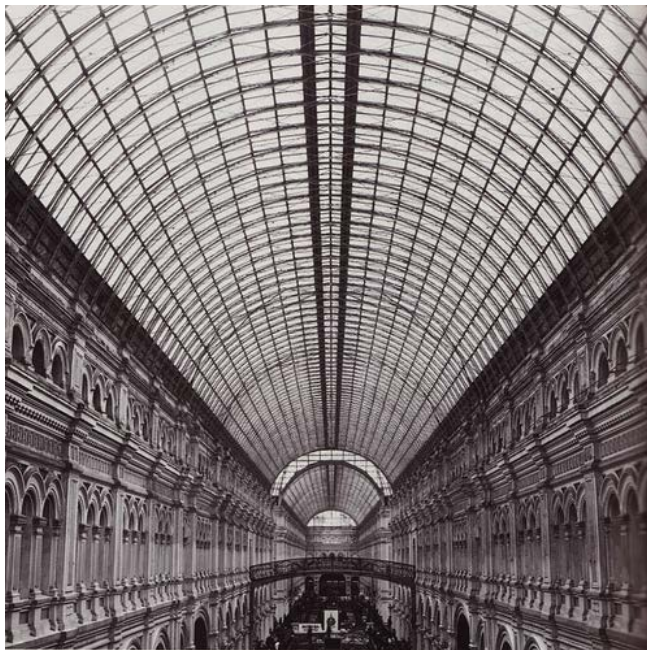


Рис. 3. Шаболовская радиобашня: схема башни и характерные фрагменты пересечения стержней, обруча и кольца жесткости между секциями

Project Vladimir G. Shuhkov (1853-1939)



Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich



Department Store Gum,
Moscow, 1889-93

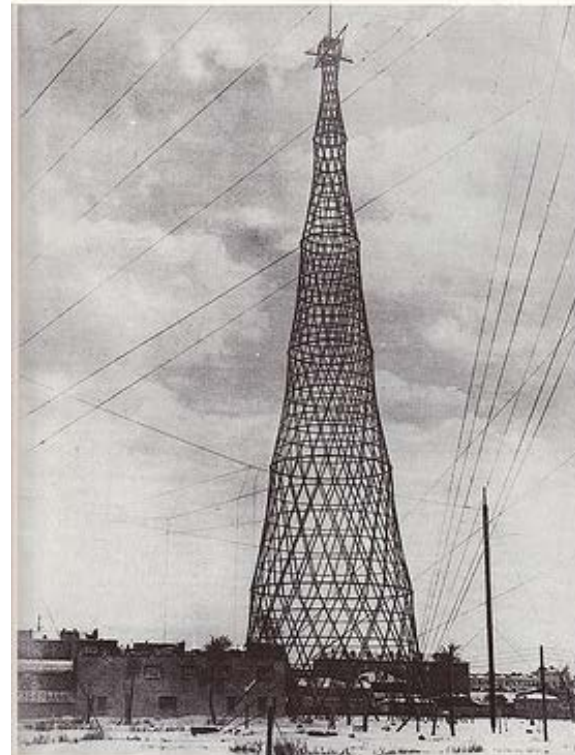


Abb. 178
Sabolovka-Radioturm in
Moskau, 1919–1922.
Historisches Foto
[Archiv Šušev-Architektur-
museum]

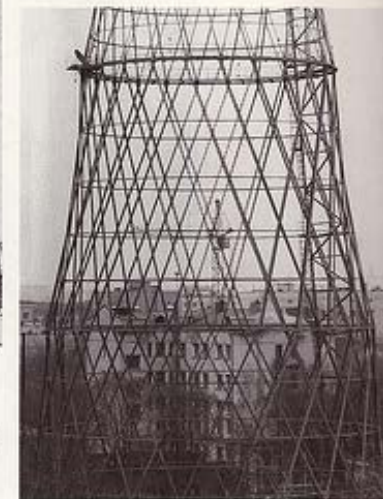
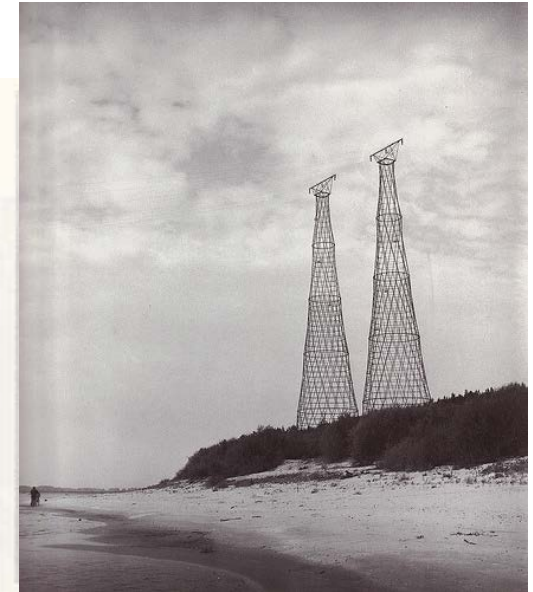


Abb. 179
Sabolovka-Turm mit
später eingebautem Aufgang
(rechts) und mit 1973
angebrachten Verstärkungs-
ringen im dritten Abschnitt
[Foto: R. Groefe, 1989]

Project Vladimir G. Shuhkov



How to measure and model complex steel rods in 3D space ?

- + Resolution?
- + Accuracy?
- + Integration of rod models (combination of CAD and photogrammetry)



Sensors

- + UAV photogrammetry
- + GPS/INS for autopilot
- + Laserscanning
- + GPS for control points and for control of high frequency movements



Falcon-8 flight

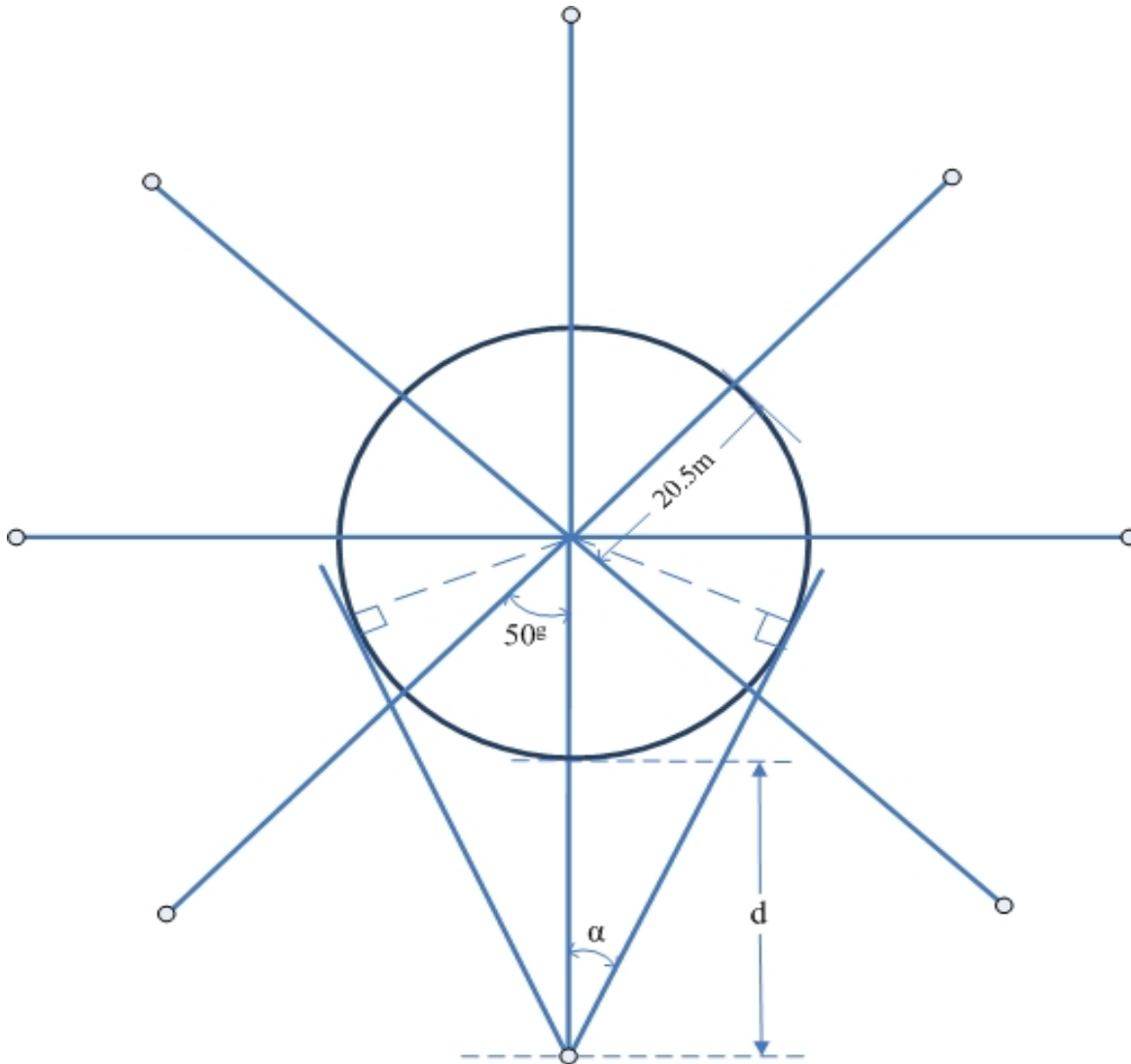
AscTec Falcon 8 - Facts

500 g load
max 20 min flight time
max 10 m/s wind speed
redundancy through 8 rotors
GPS, height sensor, compass, IMU
max. Total weight 1,8 kg

Camera Sony NEX-5

16mm lens fix, 14.2 Mpi, APS-C,
focus manually, live video,
pi = 5micron

8-Star Design



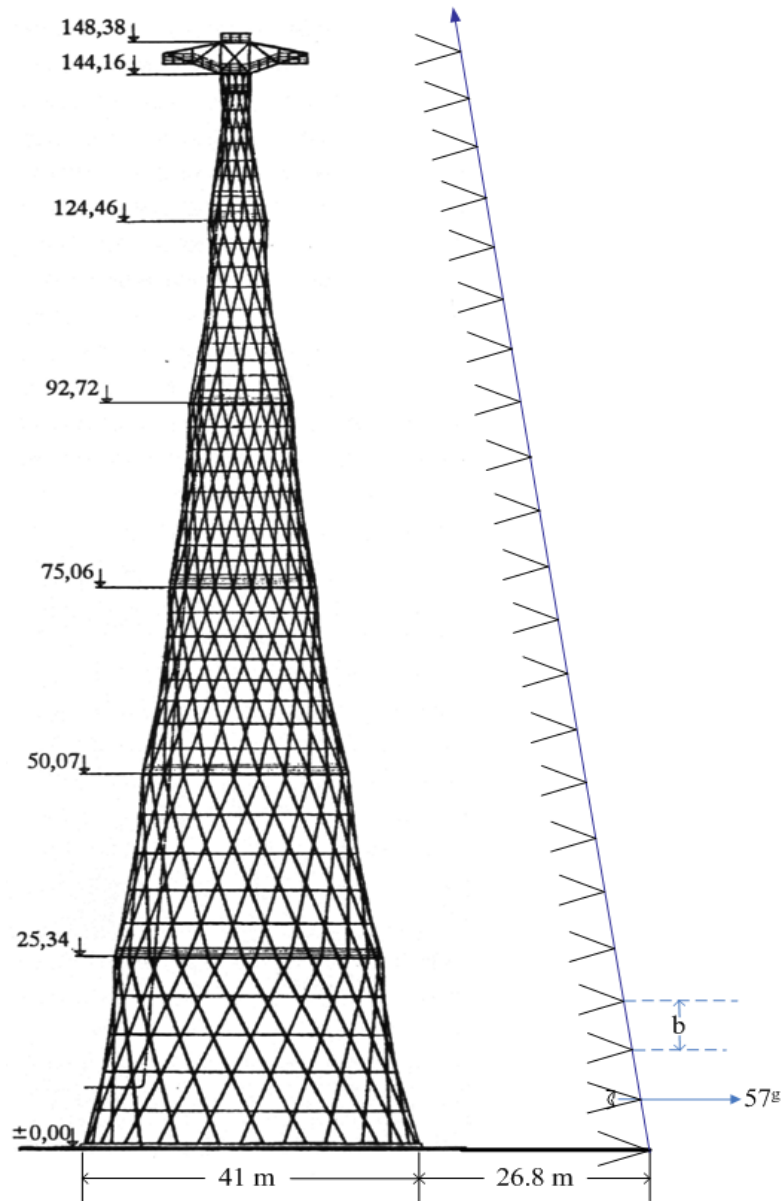
$d \approx 26.8 \text{ m}$

$\alpha = 28.5^\circ$

Object format (frontal):
25.8x38.7 sqm

MB = 1:1677

Footprint: 8.4 mm foreground



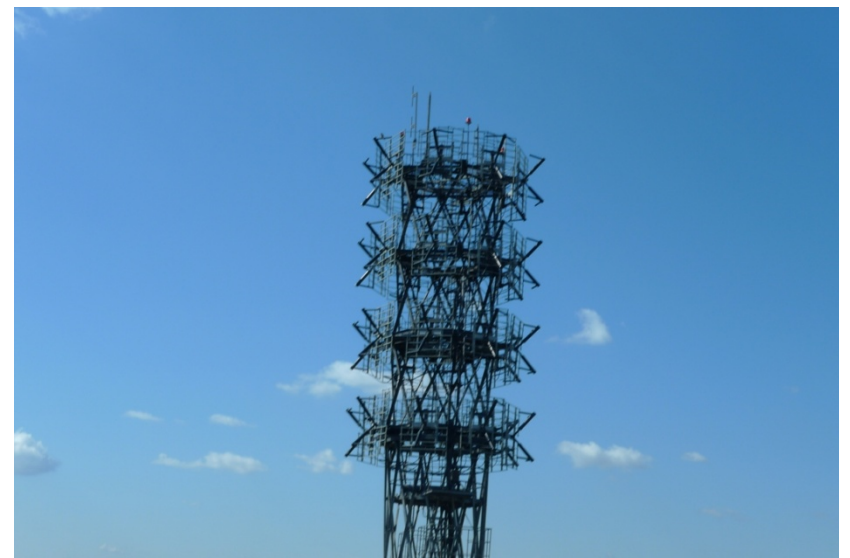
Network design:

$80\%l > b = 7.7\text{m}$

➤ 20 images per strip

➤ 160 images in total

Schabolovskaya – UAV images





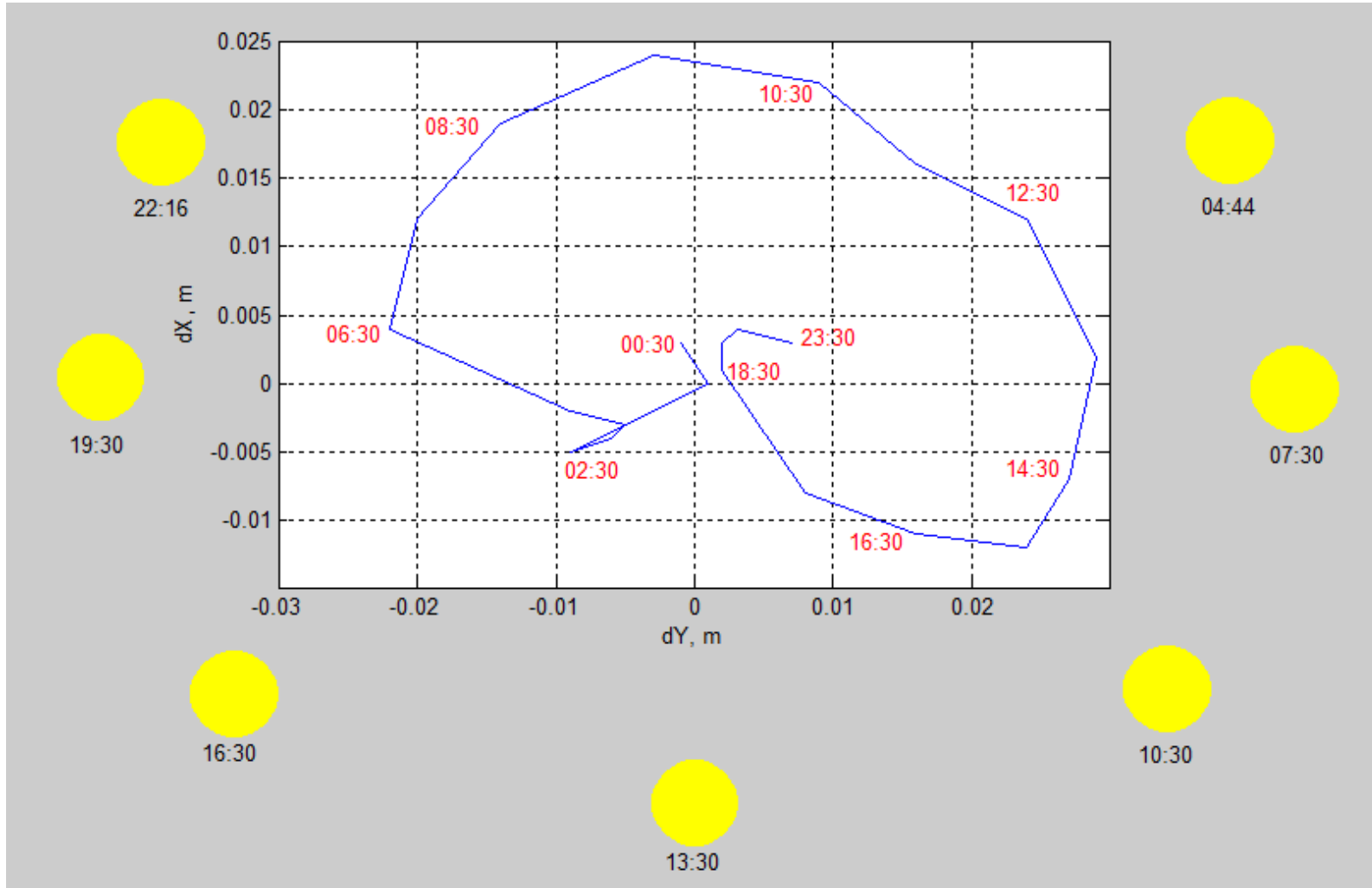
Schabolovskaya - terrestrial stereos



Schabolovskaya - terrestrial stereos

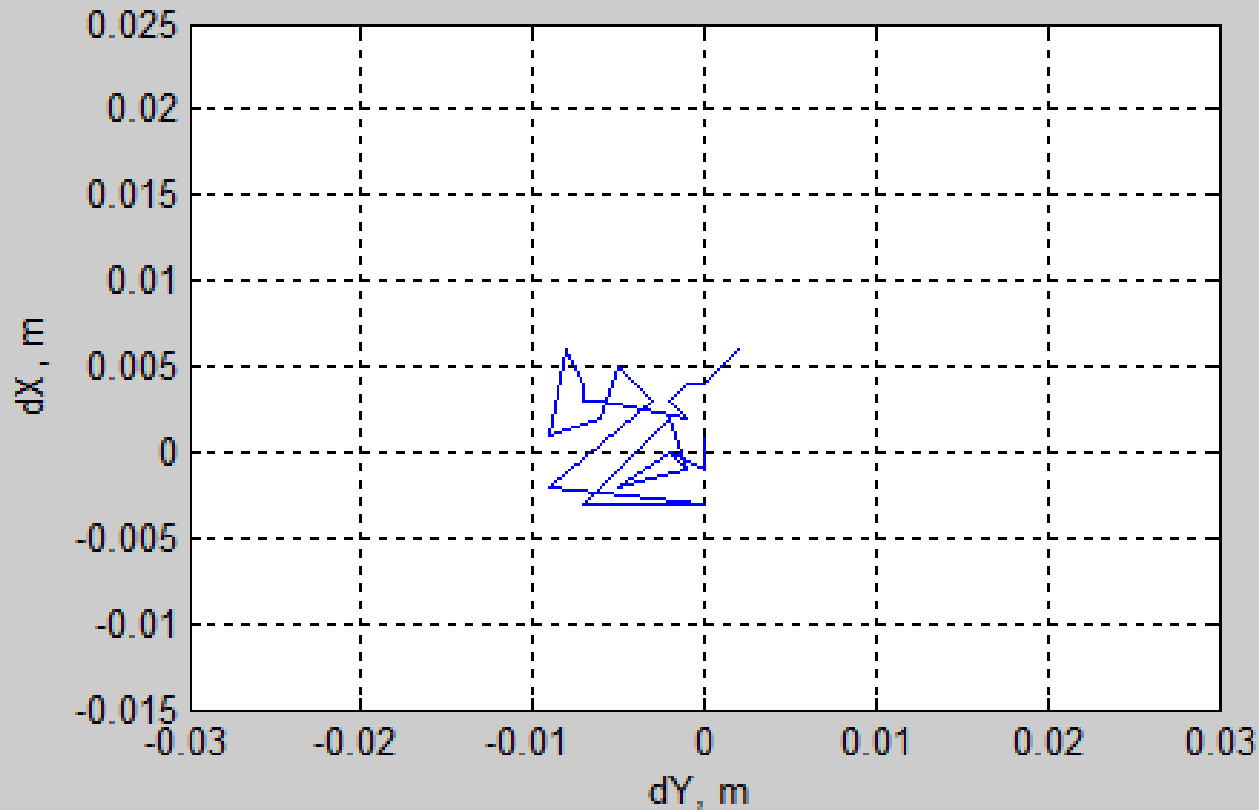


Movement of tower top, measured by GPS Sunny

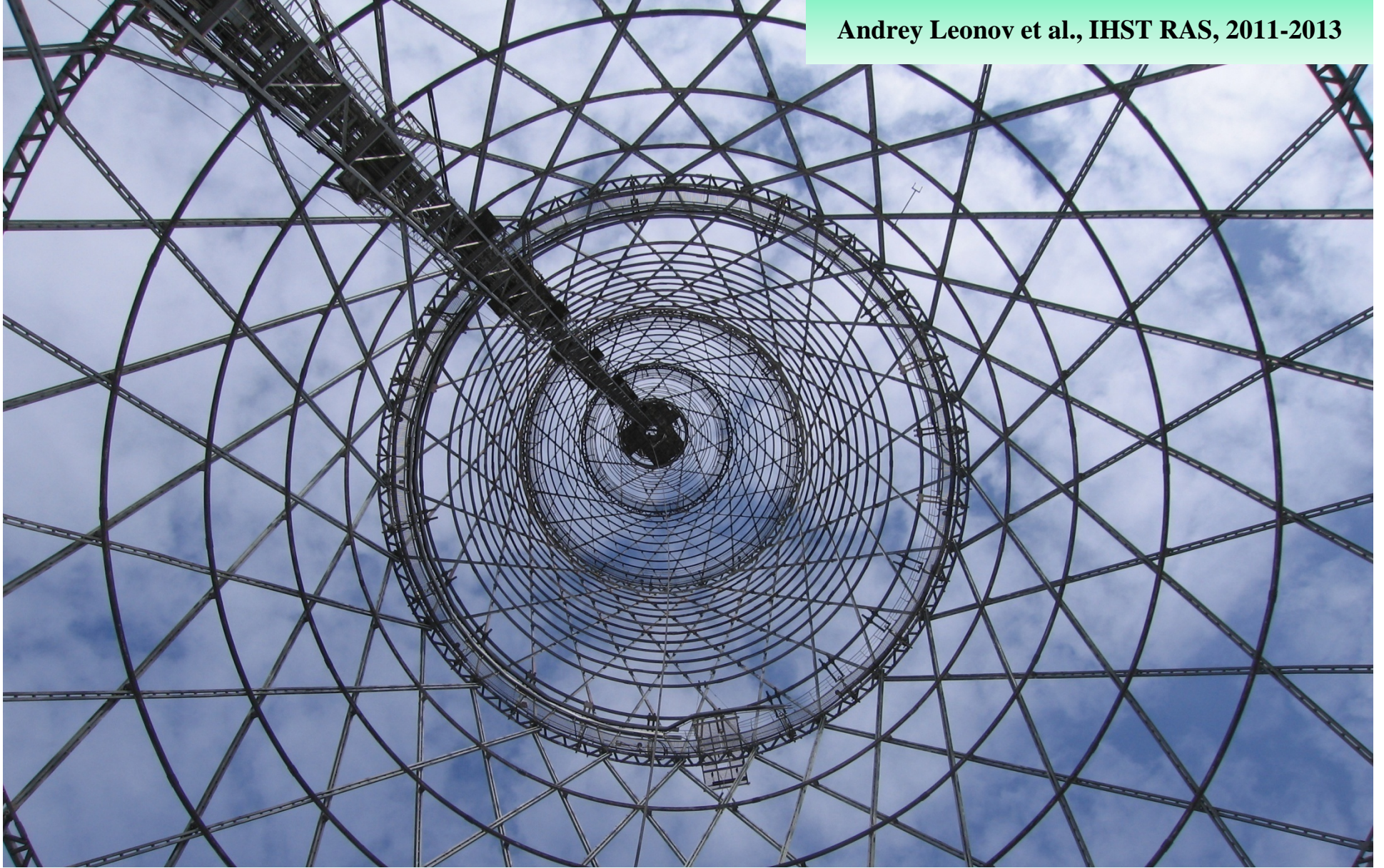


$dX < 4 \text{ cm}$
systematic

Movement of tower top, measured by GPS Overcast



$dX < 1$ cm
noisy



Laser scanning and 3D modeling of the Shukhov tower on Shabolovka (Moscow, Russia)

Laser-scanning of Schabolovskaya

Andrey Leonov

Russian Academy of Sciences, Vavilov Institute for the
History of the Science and Technology.

Support of Trimetari Consulting (St. Petersburg, Russia)

Polibino image processing

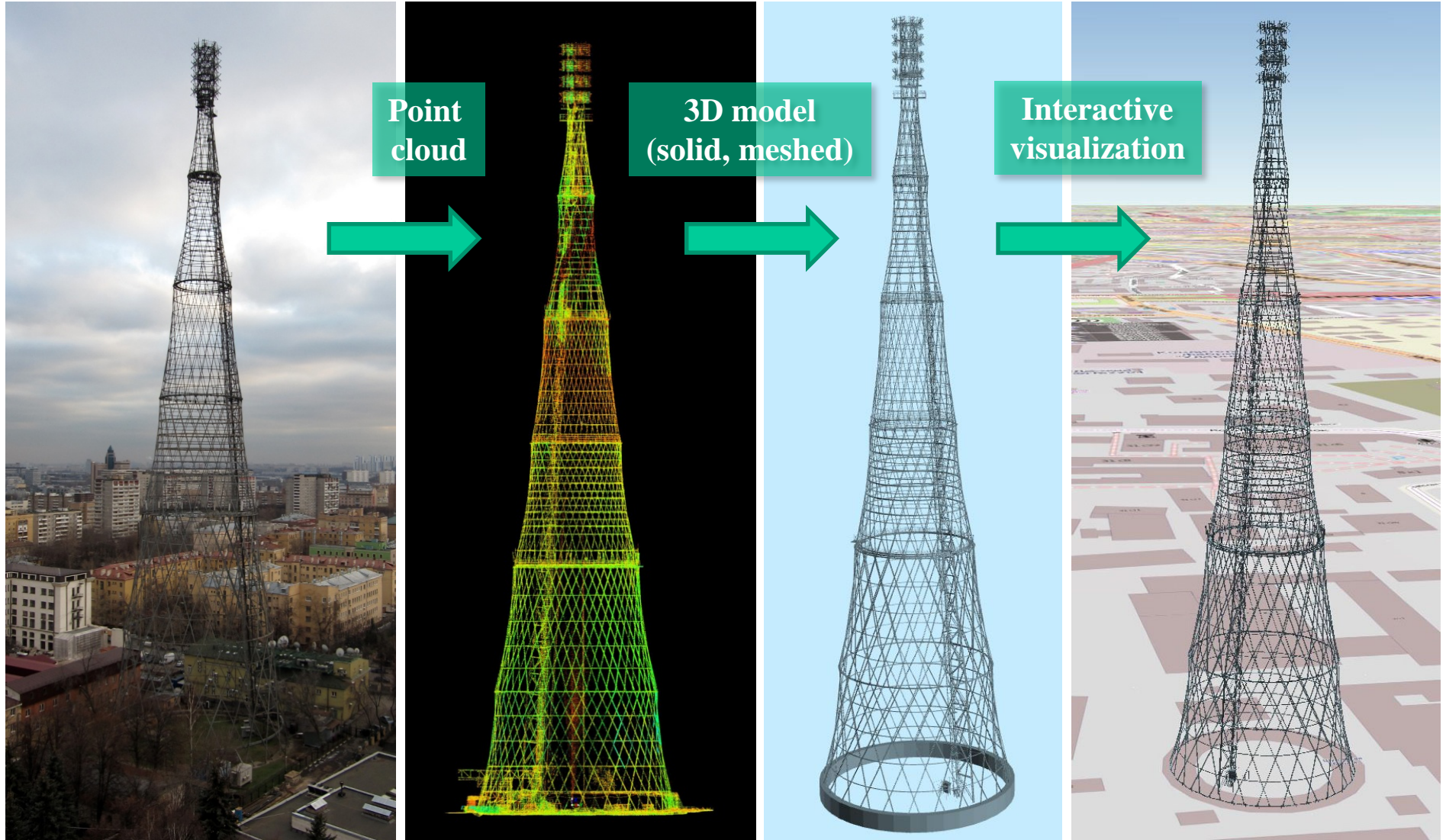
S. Zheltov, S.V. Skryabin

GosNIIAS (State Research Institute of Aviation System,
Moscow)

Prof. A. Mikhaylov

Moscow State University

Stages of the project



Laser scanning



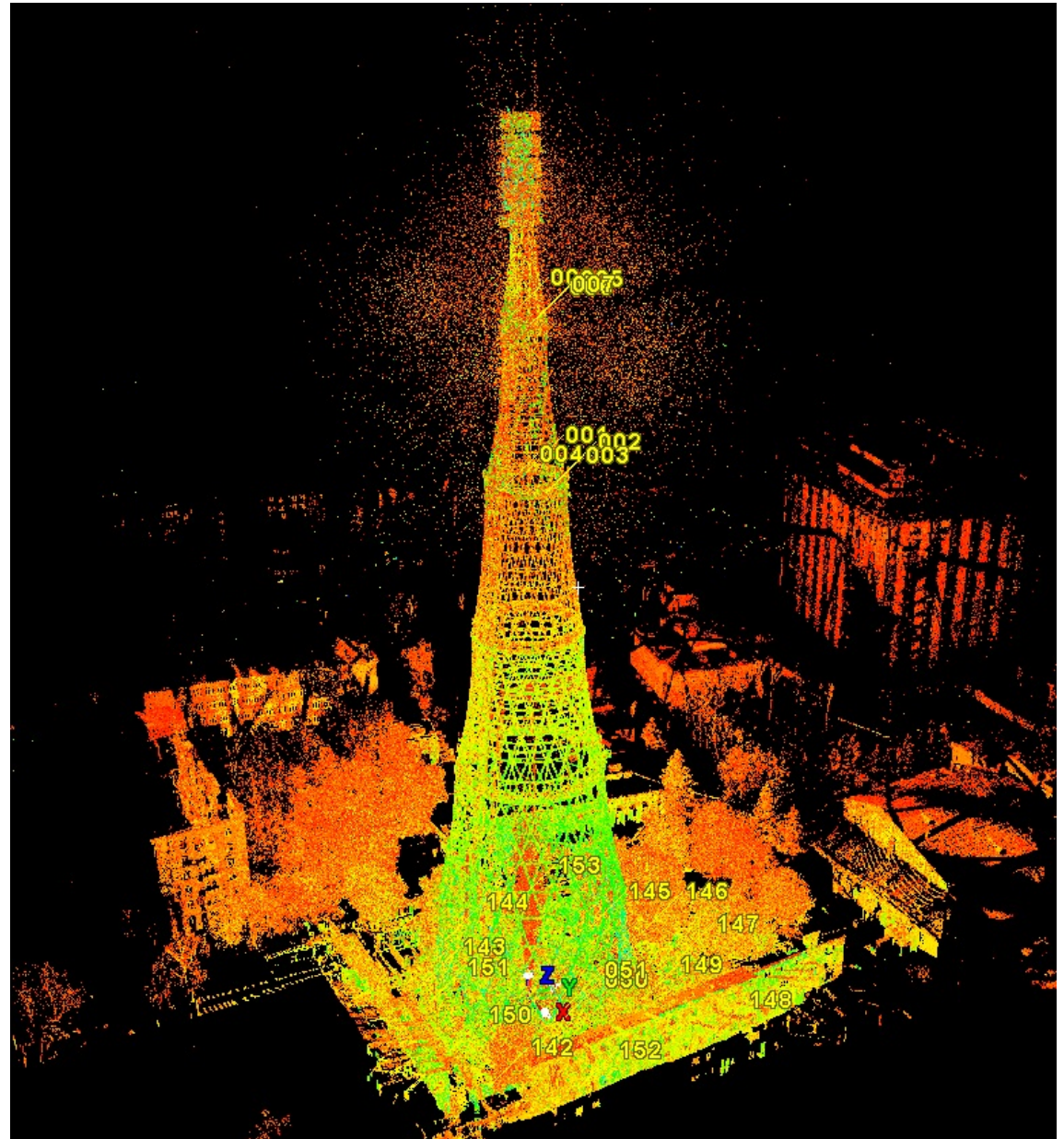


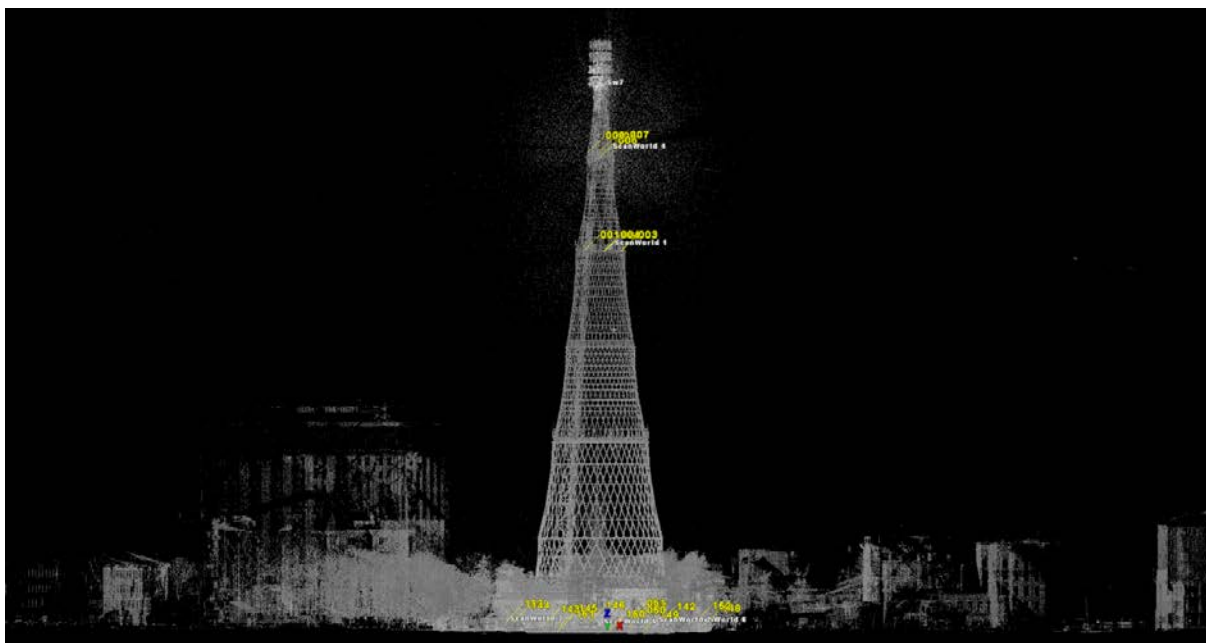
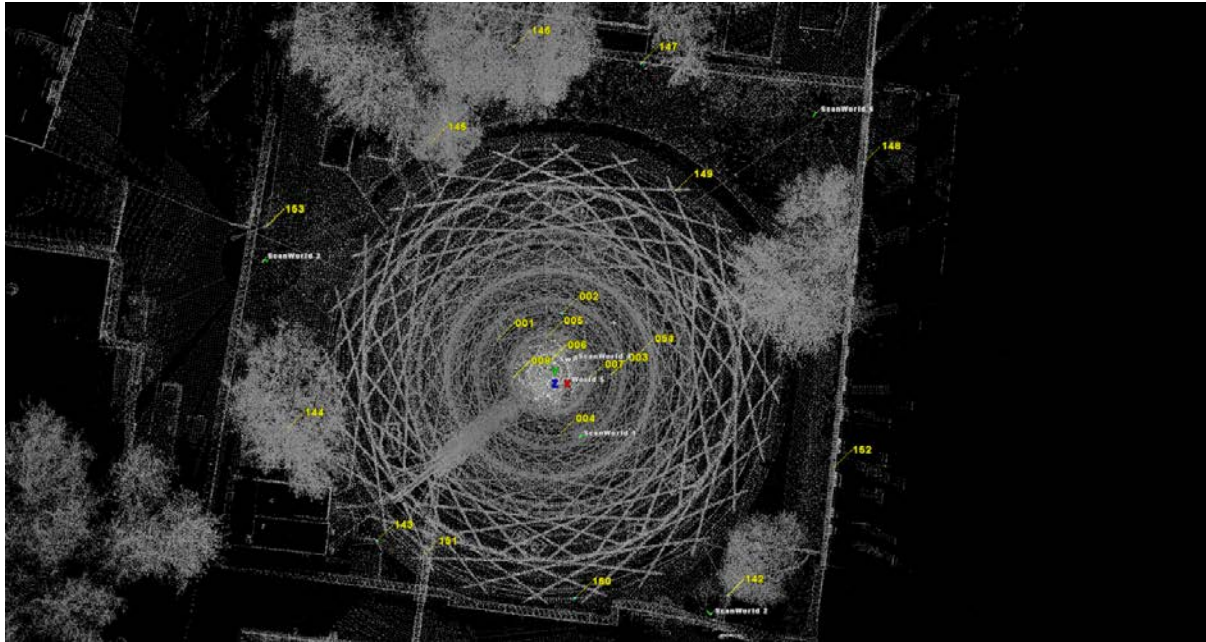
Laser scanning



FARO Focus3D, level 141 m

Schabolovskaya, point cloud





2 working days,
7 scan-stations

Data processing:
Leica Cyclone

100 mln. points
(65 mln. after cleaning)

Accuracy of scans'
inter-alignment
is 7 mm

Geo-referencing of the model



Accurate geo-referencing
to the Moscow city
geodetic network

Transformation
parameters:

dE: 7125,388323 m

dN: 5604,231434 m

dH: 134,954 m

Rot: -6° 02' 06.882424''

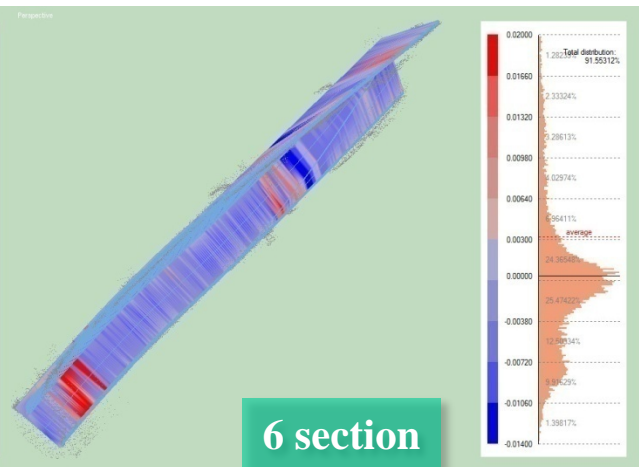
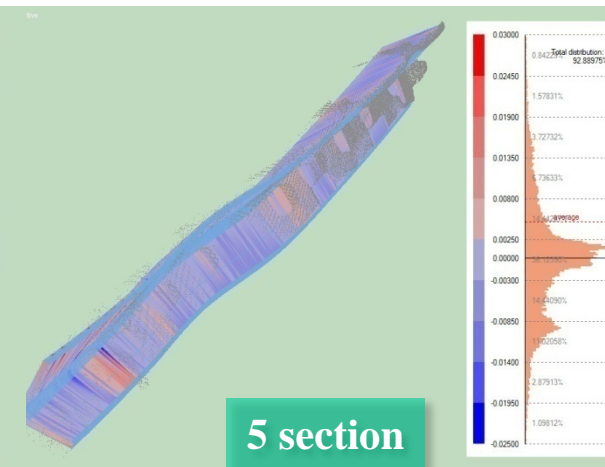
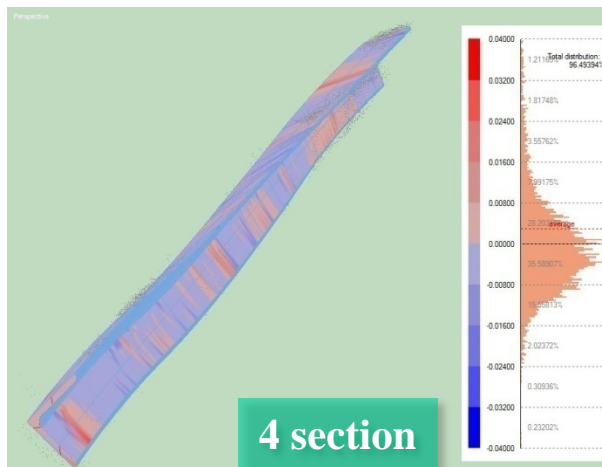
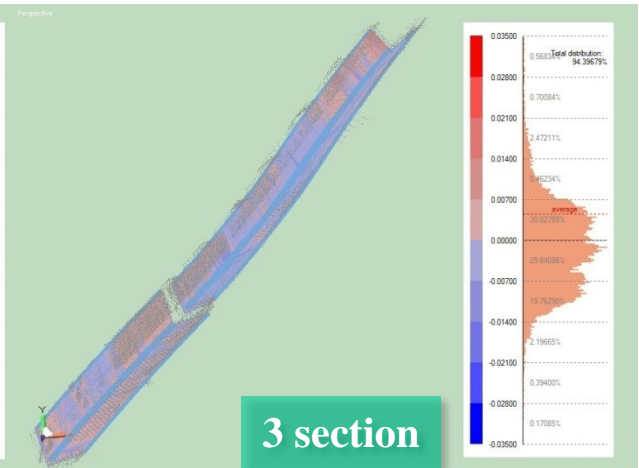
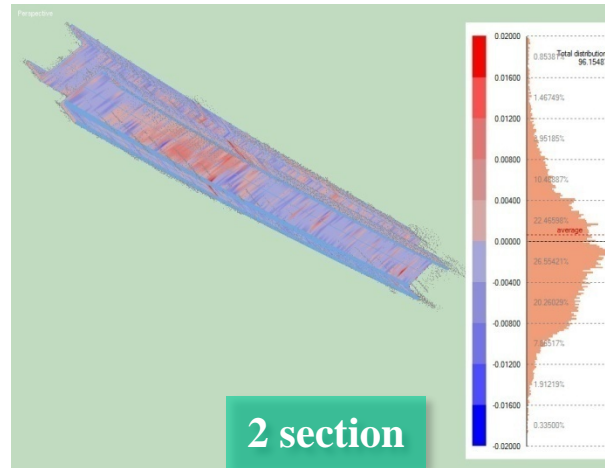
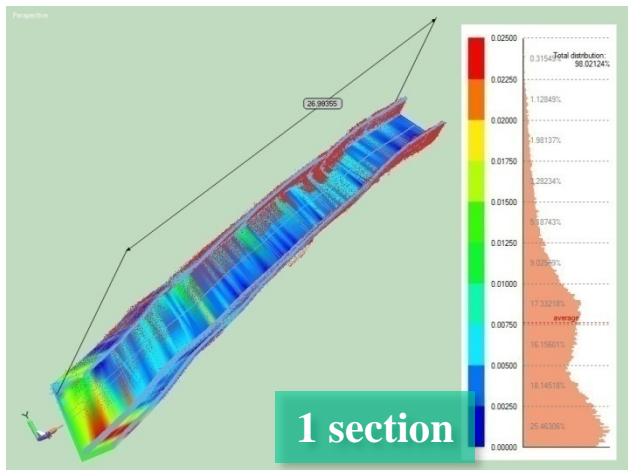


Individual modeling of the main elements (legs and rings)

10-12 cross-sections for each element adjusted in the point cloud

The profile interpolated between cross-sections

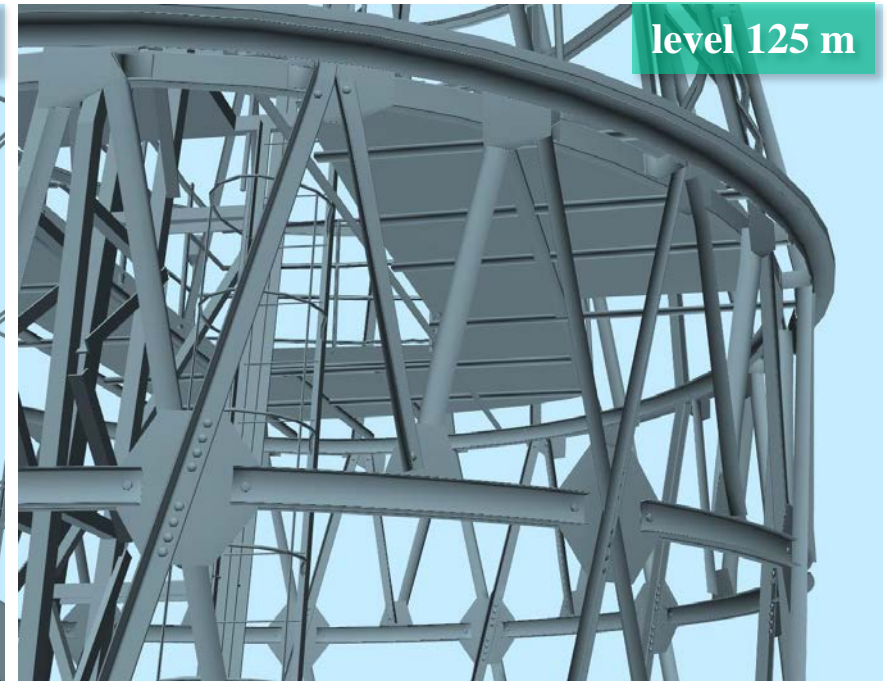
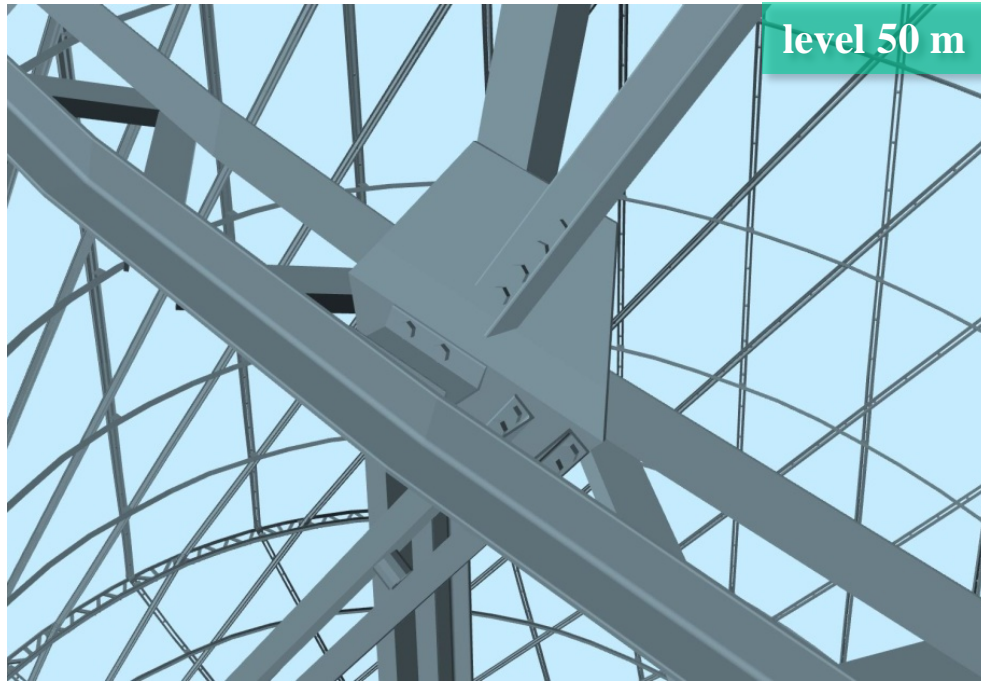
The average accuracy of the fit of the 3D model to the point cloud is 2-8 mm for different elements



Point cloud + cross-sections + 3D model

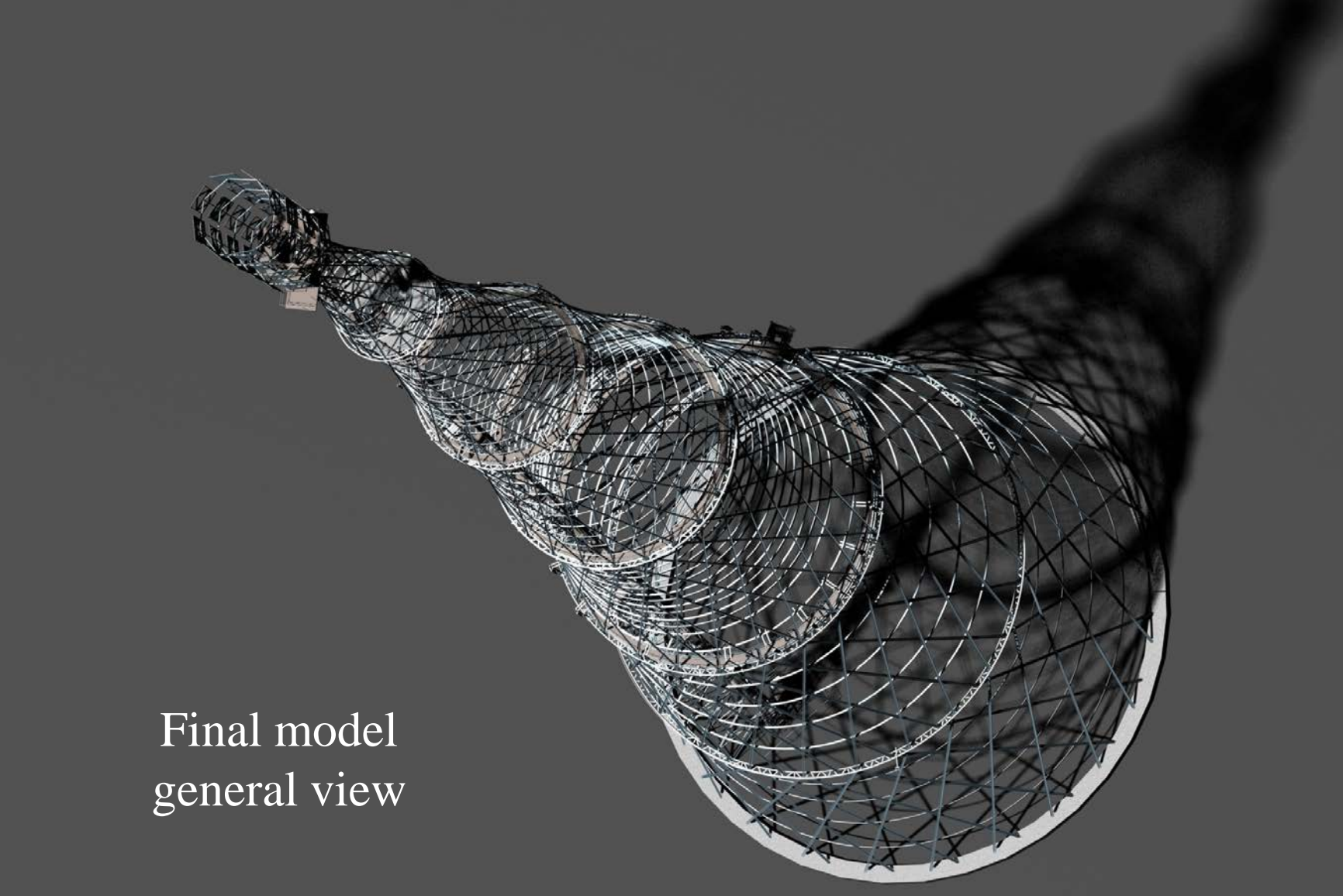


Modeling of junctions (generic, reality-based)



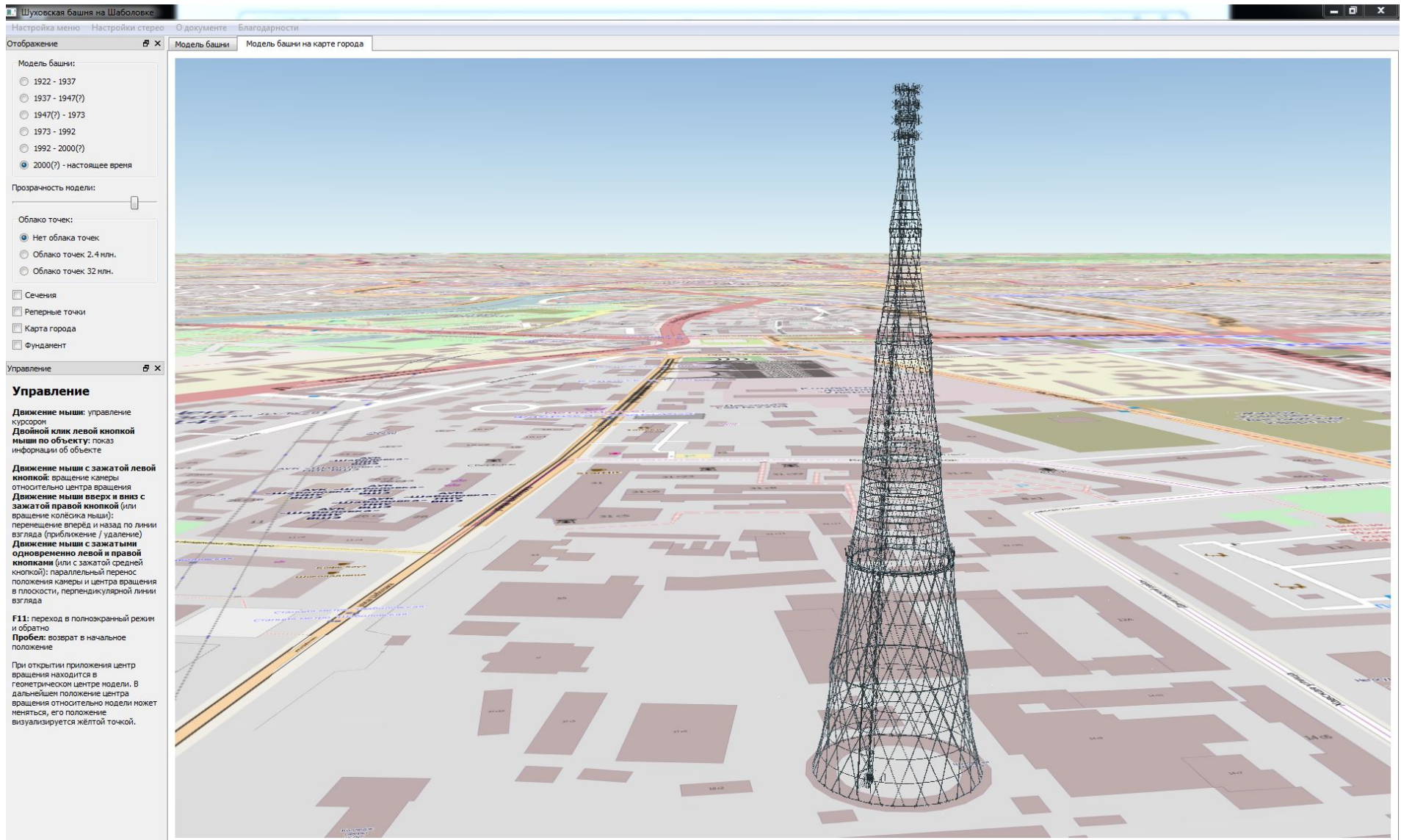
Point cloud + 3D model





Final model
general view

Model on a virtual globe, interactive visualization



Шуховская башня на Шаболовке

Настройка меню Настройки стерео О документе Благодарности

Отображение Модель башни Модель башни на карте города

Модель башни:

- 1922 - 1937
- 1937 - 1947(?)
- 1947(?) - 1973
- 1973 - 1992
- 1992 - 2000(?)
- 2000(?) - настоящее время

Прозрачность модели:

Облако точек:

- Нет облака точек
- Облако точек 2.4 млн.
- Облако точек 32 млн.

Сечения

Реперные точки

Карта города

Фундамент

Управление

Управление

Движение мыши: управление курсором

Двойной клик левой кнопкой мыши по объекту: показ информации об объекте

Движение мыши с зажатой левой кнопкой: вращение камеры относительно центра вращения

Движение мыши вверх и вниз с зажатой правой кнопкой (или вращение колёсика мыши): перемещение вперёд и назад по линии взгляда (приближение / удаление)

Движение мыши с зажатиями одновременно левой и правой кнопками (или с зажатой средней кнопкой): параллельный перенос положения камеры и центра вращения в плоскости, перпендикулярной линии взгляда

F11: переход в полноэкранный режим и обратно

Пробел: возврат в начальное положение

При открытии приложения центр вращения находится в геометрическом центре модели. В дальнейшем положение центра вращения относительно модели может меняться, его положение визуализируется жёлтой точкой.

Polibino tower



ВСЕРОССИЙСКАЯ ПРОМЫШЛЕННАЯ
И ХУДОЖЕСТВЕННАЯ ВЫСТАВКА.
г. Нижний Новгород, 1896 г.



All-Russian Exhibition in Nizhny Novgorod in 1897

Polibino tower – UAV in operation



Polibino tower – manual control



Polibino tower – UAV crash



Polibino tower – substitute platforms



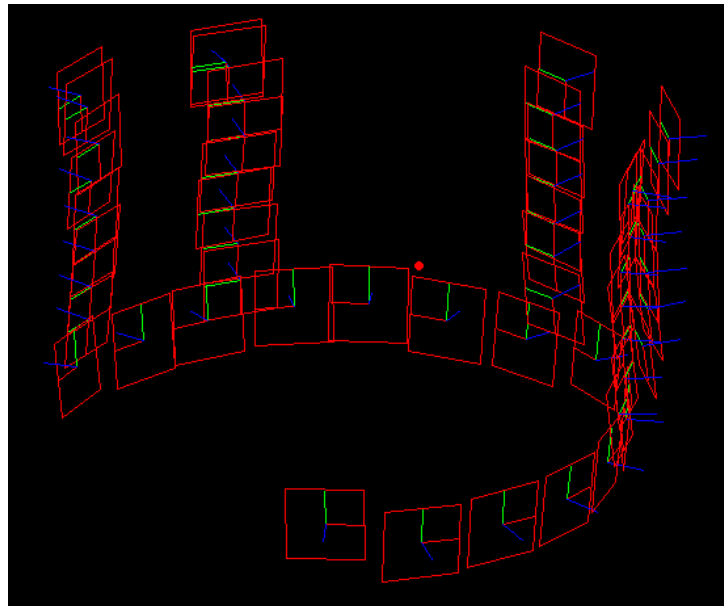
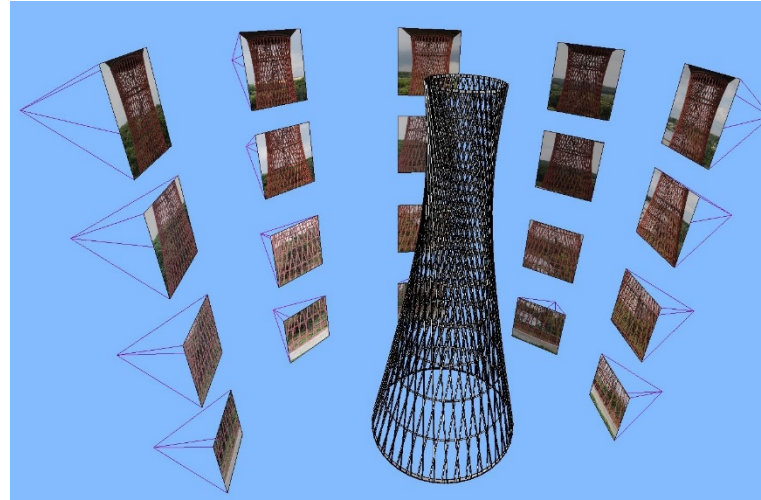
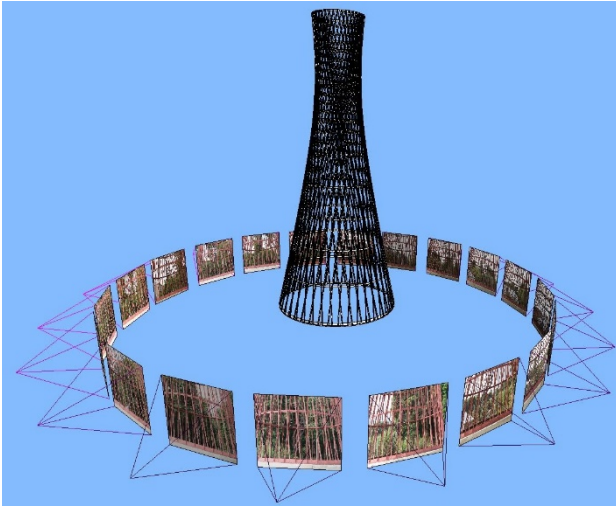
Polibino terrestrial stereo



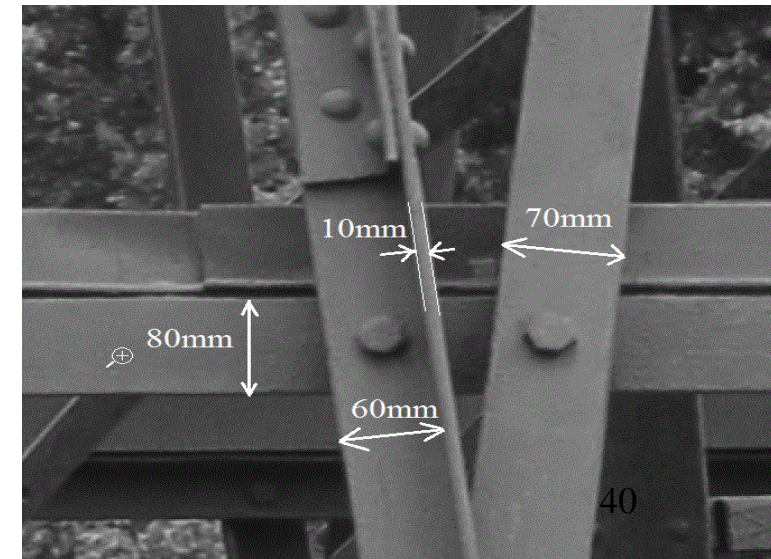
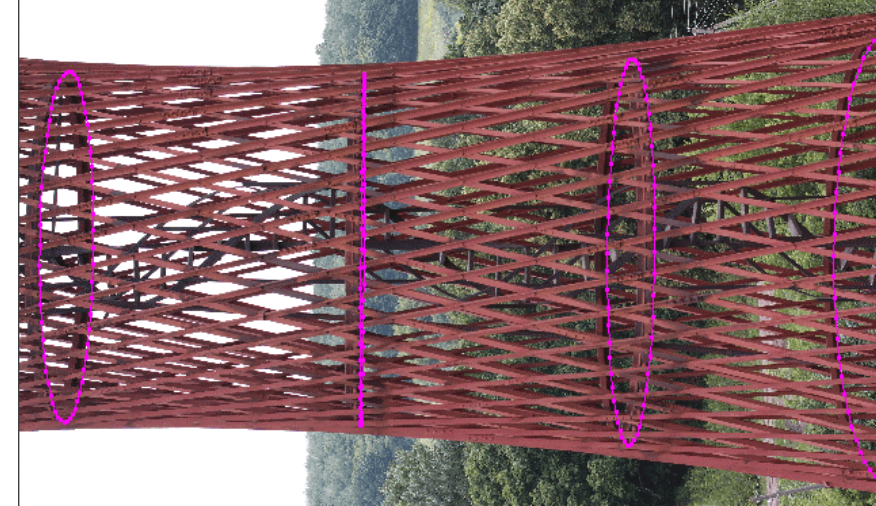
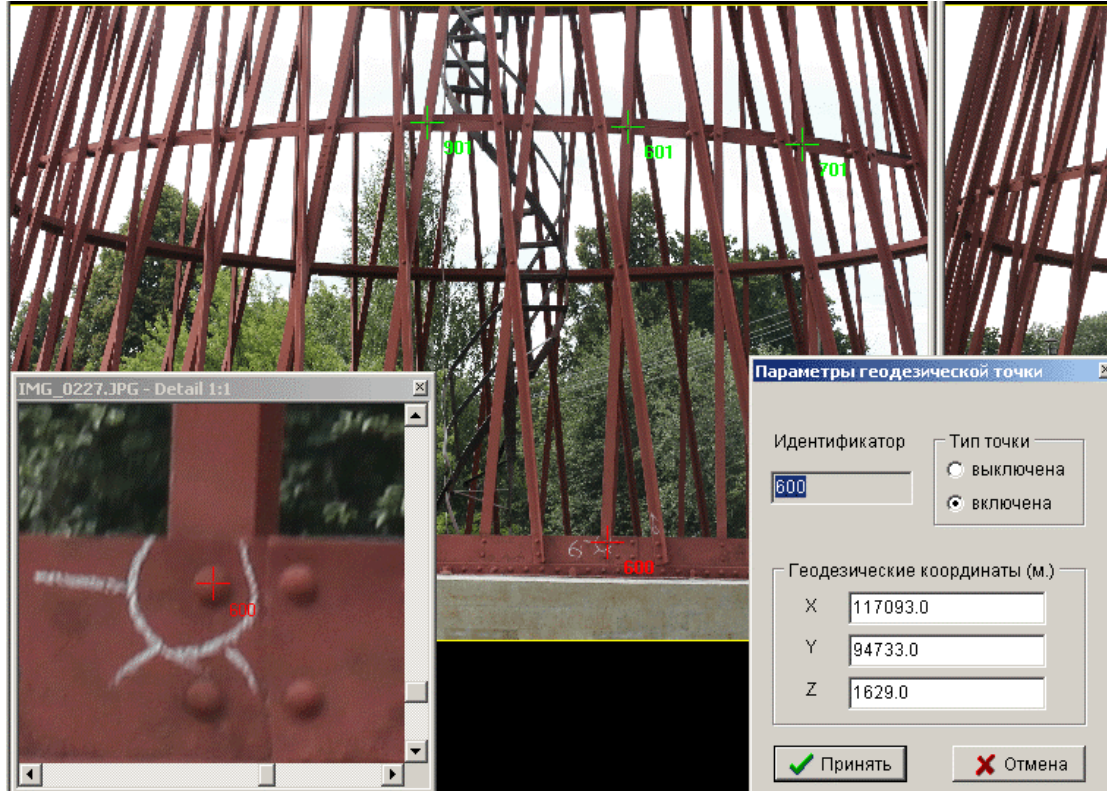
Polibino terrestrial stereo



Polibino terrestrial network



Polibino results



Shuhkov Tower Buchara



Problem
Occlusions

A history of UAV failures

- + Pinchango/Peru: Crash of mini-helicopter (bad fuel, dust)
- + Randa/Switzerland: Mini-helicopter almost hit rock face (high altitude < 2000m)
- + Palpa/Peru: Mis-functioning of mini-helicopter because of high altitude (1600 m ASL)
- + Drapham Dzong/Bhutan: Quadrocopter: Loss of 2 batteries (cold), failure of autopilot, 2 fall-downs
- + NUS/Singapore: Octocopter: Fall-down on roof
- + Moscow/Russia: Octocopter: Failure of navigation system (mobile antennas)
- + Polibino, Russia: Octocopter: Crash through total failure of navigation system

UAV specific problems

- + Cheap sensors – low data quality (GPS/IMU)
Navigation/positioning often not accurate enough
- + Interference with external microwave sources: Mobile antennas – electronic compass; control signal disturbance
- + Cameras (off-the shelf), 24Mpi, temperature instability, but main problem: Lens (colour refraction/colour seams, unsharpness in corners)
- + Errors in system software (spurious images, images and GPS/IUM not synchronized)
- + Overlap often irregular
- + Sometimes oblique images, complex networks
- + Much room for improvement of data processing methods

Conclusions

- + Model helicopters are very flexible devices for recording (cameras, orientation, navigation, real-time capabilities)
- + Cost-efficient
- + Many diverse applications, if area is not too large

But:

- + **Technology (system hard- and software) not mature**
- + **Much room for improvement of data processing methods**
- + **Flight permissions, safety concerns**

