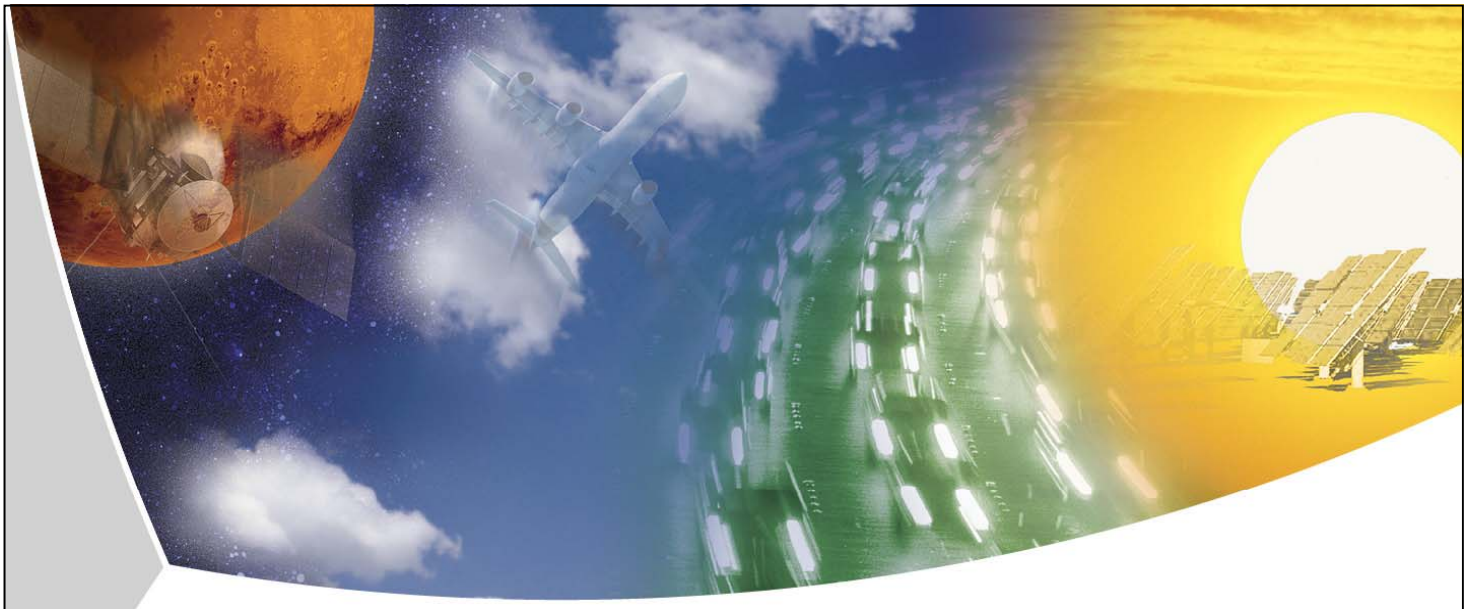

The Bright Future of High Resolution Satellite-Will Aerial Photogrammetry Become Obsolete

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DLR für Luft- und Raumfahrt e.V.
in der Helmholtz-Gemeinschaft

Outline

- Current optical high end high resolution technology
- High resolution optical satellite EO-Programs
- Commercial space segments
- Data fusion with AIS and radar sensors
- HiROS **Hi**gh **R**esolution **O**ptical Satellite **S**ystem
- Examples for real time 3D change detection
- Conclusion

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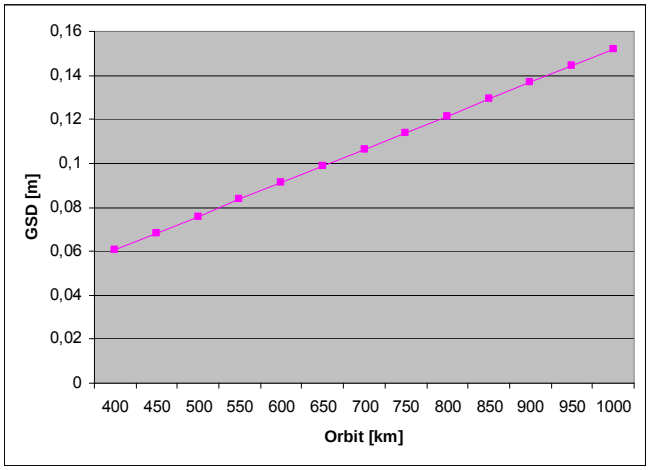
Current optical high end high resolution technology

LAUNCH:	April 24, 1990
	from space shuttle Discovery (STS-31)
DEPLOYMENT:	April 25, 1990
MISSION DURATION:	***Up to 20 years***
SERVICING MISSION 1:	December 1993
SERVICING MISSION 2:	February 1997
SERVICING MISSION 3A:	December 1999
SERVICING MISSION 3B:	February 2002
SERVICING MISSION 4:	May 2009

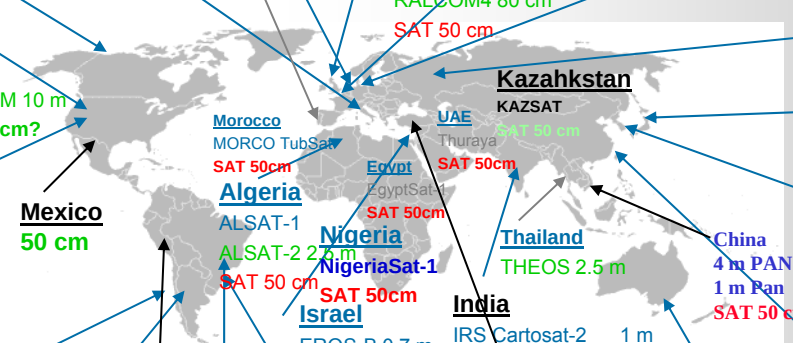


➔f : 57.6 m
➔F#: 24 / PAN
➔D 2.4 m

High resolution optical satellite EO-Programs

- ***Current Status***
- ***Announced Future Programs***
- ***Not Announced Future Programs*** ***(Budget not defined & Time Schedule not clear)***

≈ 15-20 Satellites 0.5 m GSD



Canada
SAT 50 cm

Italy
SAT 50 cm

Spain
SEOSAT
2.5 m
Sat 50 cm

ESA
SAT 50 cm

UK
Surrey
Mini-Sats
TopSat 2.86 m
DMC 1&2 4m
AlSat1&2 2.5 m
RALCOM4 80 cm
SAT 50 cm

France
SPOT-5 2.5 m
Pleiades 1&2 0.7 m
Helios 1&2 1 m

Germany
RapidEye 6.5 m
SAT 50 cm

RUSSIA
Resurs- DK 1 m
KOSMOS 1 m
IKI 50 cm

US CIVIL
Government
EOS Series
LandSat Series:LDCM 10 m
KH-12/5: 10 cm / 5 cm?

Kazahkstan
KAZSAT
SAT 50 cm

Japan
ADEOS
ALOS 2.5m
IGS
SAT 50 cm

Morocco
MORCO TubSat
SAT 50cm

UAE
Thuraya
SAT 50cm

Egypt
EgyptSat-2
SAT 50cm

US Commercial
IKONOS-2 1 m
Orbview-3 1m
GeoEye-1(OrbView-5) 0.41 m
DigitalGlobe
QuickBird 0.6 m
WorldView-1 0.45 m
WorldView-2 0.5 m

Mexico
50 cm

Algeria
ALSAT-1
ALSAT-2 2.5 m
SAT 50 cm

Nigeria
NigeriaSat-1
SAT 50cm

Thailand
THEOS 2.5 m

China
4 m PAN
1 m Pan
SAT 50 cm

Korea
KOMPSAT-1 6.6 m
KOMPSAT-2 1 m
KOMPSAT-3 0.7 m
SAT 50 cm

Israel
EROS-B 0.7 m
EROS-A 1.9 m
OPTSAT-3000

India
IRS Cartosat-2 1 m
IRS-P5 Carosat-1 2.5 m
SAT 50cm

Taiwan
FormoSat-2
Follow-on 2m-2.5m
FormoSat-2 2m-2.5m
SAT 50cm

Chile
FASat-Allta
ChileSat 2.5 m

Argentina
SAC-C 35m
NASA/CONAE
SAT 50 cm

Brazil
MECO series
SAT 50 cm

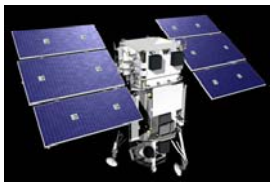
Brazil/China
CBERS 3&4 5 m

Turkey
Göktürk-1 0.5 m
Göktürk-2 2.5 m
Göktürk-3 1 m – 0.5 m

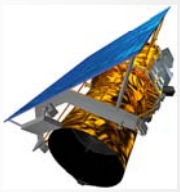
Australia
SAT 50 cm

Peru
50 cm

Commercial or dual use optical space segments

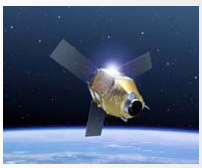


WV1: 0.5 m GSD



Geo Eye 0.41 m GSD

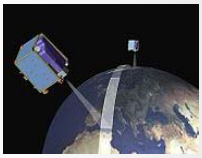
WV2 0.5 m GSD



Pleiades 1 m GSD

Example DLR Proposal

HiROS 0.5 GSD



RapidEye 6.5 m GSD

Example: HiROS design goals

Main key parameter of the optical HiROS payload

- Revisit, actuality and imaging time
  (**any area** worldwide shall be scanned within **24 h** by one of the satellites)
- Size of imaging area (36…60 km x 36…60 km)
- Target recognition (high color resolution, 3D capability)
- Special data products for MIL and security applications
- Data processing time minimization

➔ 3 Satellite System with 0.5 m GSD PAN ←

HiROS a End to End system proposal

Options: (1) Auto Indetif. of Ships, (2) Night Vision IR, (3) Real time Image Access

HiROS Key Parameter

	HiROS-Std	HiROS-MR	HiROS-HR
Orbit [km]	490…685		
GSD	0.5…0.7		
Aperture [m]	0.75		
VIS Spectral	R,G,B,NIR		
Stereo Views	-30°,-10°,0°, +10°,+ 30°		
TDI-Direction	bidirectional		
Nr. Pixel PAN	24,000		
Nr. Pixel MS	6,000		
Line Rate [kHz]	14		
MTF	> 12 %		
SNR	> 200*		

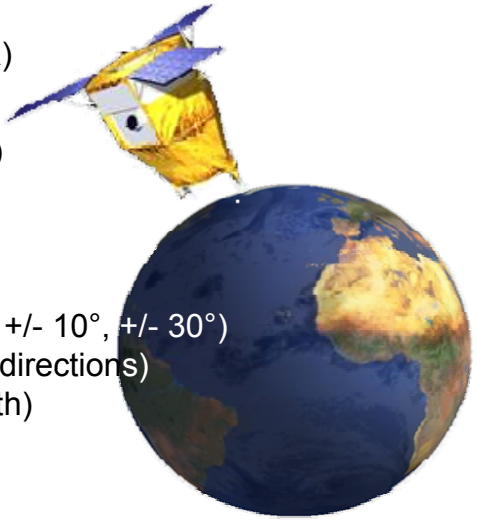
(* at 20 % albedo, (30 ° sun angle, 30 ° view angle), 10:30 Berlin)

Mission characteristics of HiROS

Long Life Time: **5 years**

Resolution:

- PAN **0.5 m GSD**
- MS **2 m** GSD (Red, Green, Blue, NIR)



High Revisit Time: any point on Earth every day

- Polar SSO (**490 km**, **7063 m/s**, **LTDN 10:30**)
- 3 satellite constellation (**120° spacing**)
- High duty cycle **10 min per orbit**

High Agility / Operability

- One- Pass Stereo Imaging (along track viewing angle of 0°, +/- 10°, +/- 30°)
- Wide Area Imaging (**five** strips of **12 km swath**, in flight all directions)
- Multi Point Imaging (Multiple small area coverage in one path)

High Down Link Capability

- Steerable X – band antenna (**600 Mbit/s** encrypted)
- Simultaneous downlink & imaging

Option [I]: IR MIR & TIR: GSD 5 m

Option [II]: Automatic Identification of Systems (Coded telecommunication)

Option [III]: Ka-Band Uplink to Geo Communication Satellites (**2 min for 12 x 12 qkm** after imaging)

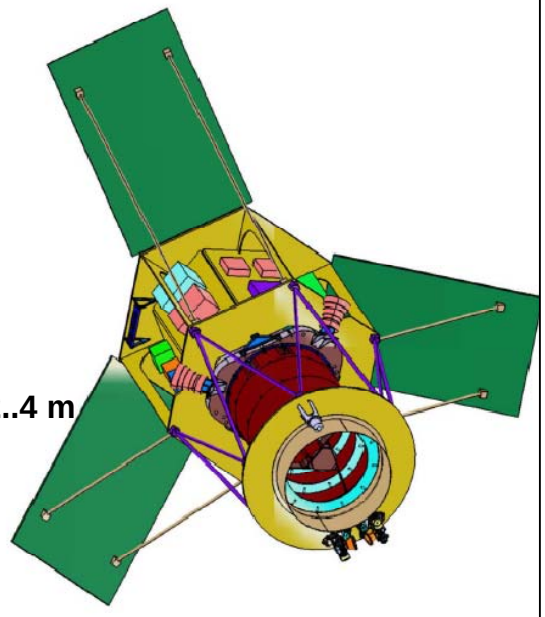
High resolution optical satellite system (Std. HiROS)

Satellite Characteristics

Mass: **820 kg (dry mass 750 kg)**

Launcher: **single launch (Rockot, VEGA…)**
multiple launch (Soyuz 2 – 1b)

Power: **380 W average**



High Pointing Accuracy & Stability:

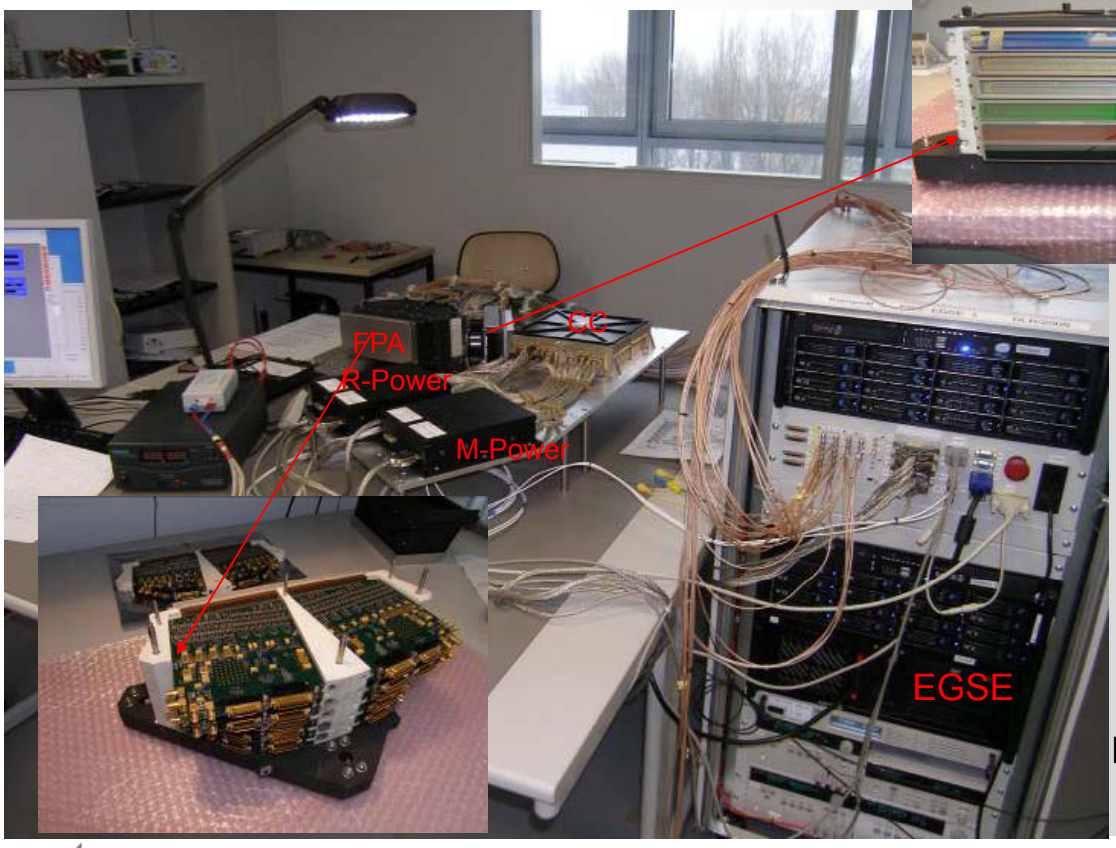
- Accuracy of orientation w/o ground control points: **+/- 2..4 m**
- Orientation relative to Nadir **+/- 30° pitch / +/- 40° roll**
- Stereo Angle along track **0°, +/- 10°, +/- 30°**
- Cross track **0° to 90°** during one path
- LoS accuracy (Jitter Stability): **0.07 arcs** / **4.83 ms**
- Co-registration between IR and HR VIS: 1/3 Pixel of IR detector = **0.7 arcs**

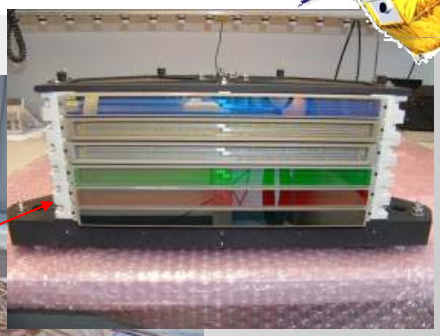
HiROS – Instrument performances

- **Mass:** **190 kg**
- **Power:** **110 W**
- **Panchromatic Channel:** **0.5 m GSD**
  450nm – 900nm
- **Multi spectral Channels:** **2 m GSD**
  450 – 520, 520 – 600, 630 – 690, 760 – 900 nm
- **Option IR Channel:**
  - MIR GSD: **5 m**
  - TIR GSD: **5 m**
- **Swath Width** **> 12 km**
- **MTF** **> 13 %**
- **SNR:** **> 200***
- **Dynamic Range:** **> 1:5000** (14 bit ADC)
- **Selectable TDI Stages:** **1, 8, 32, 64**
- **Line Rate:** **0.5…14.5 kHz** PAN / **0.5…3.6 kHz** MS

* Sun angle 30° view angle 30° albedo 20%,10:30 Berlin

Focal plane development





MTF [CT] : 52 %

MTF [LT] : 53 %

rms noise [wc] 16 LSB (40 °C)

Channel SNR >1024

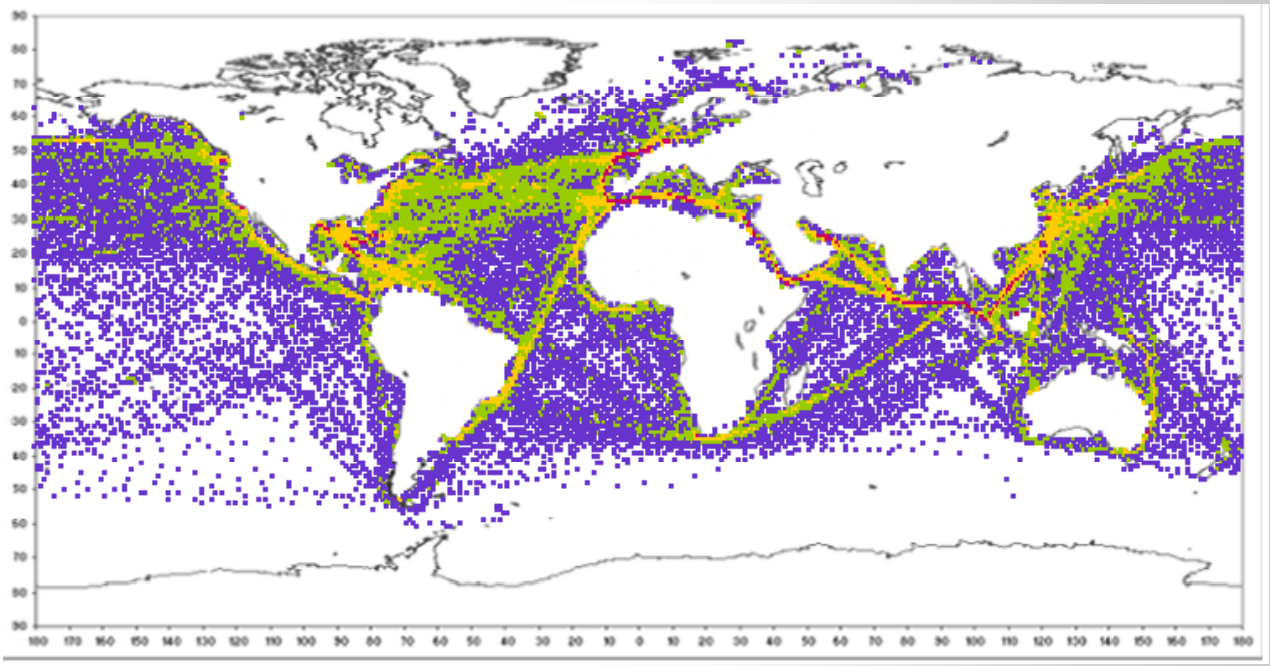
Instrument SNR 200*

Line Rate: 14 kHz

* Sun angle 30° view angle 30° albedo 20%,10:30 Berlin

Maritime Surveillance & Reconnaissance

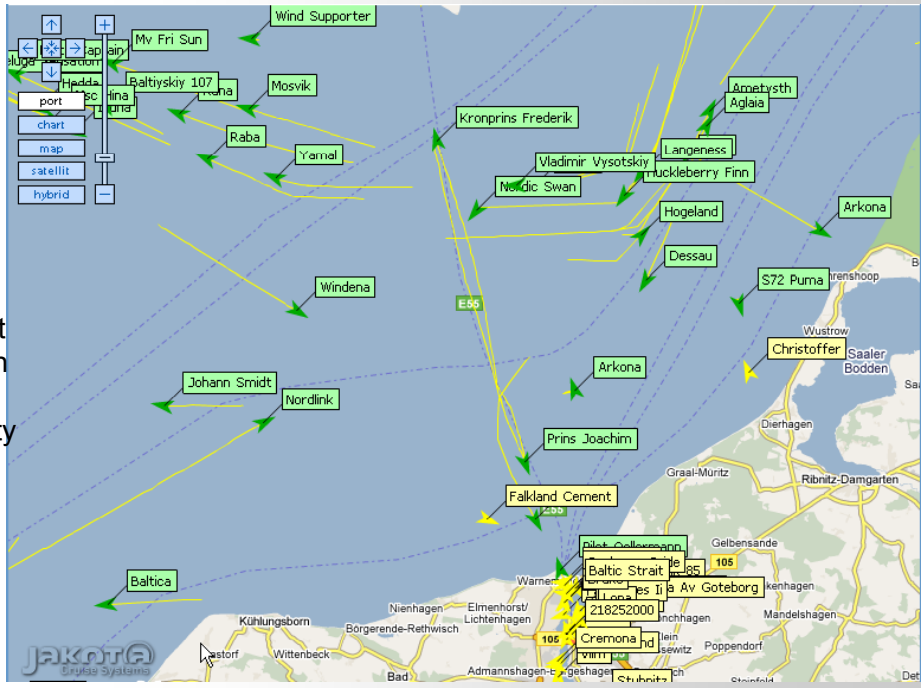
Automatic Identification System AIS



© AMVER

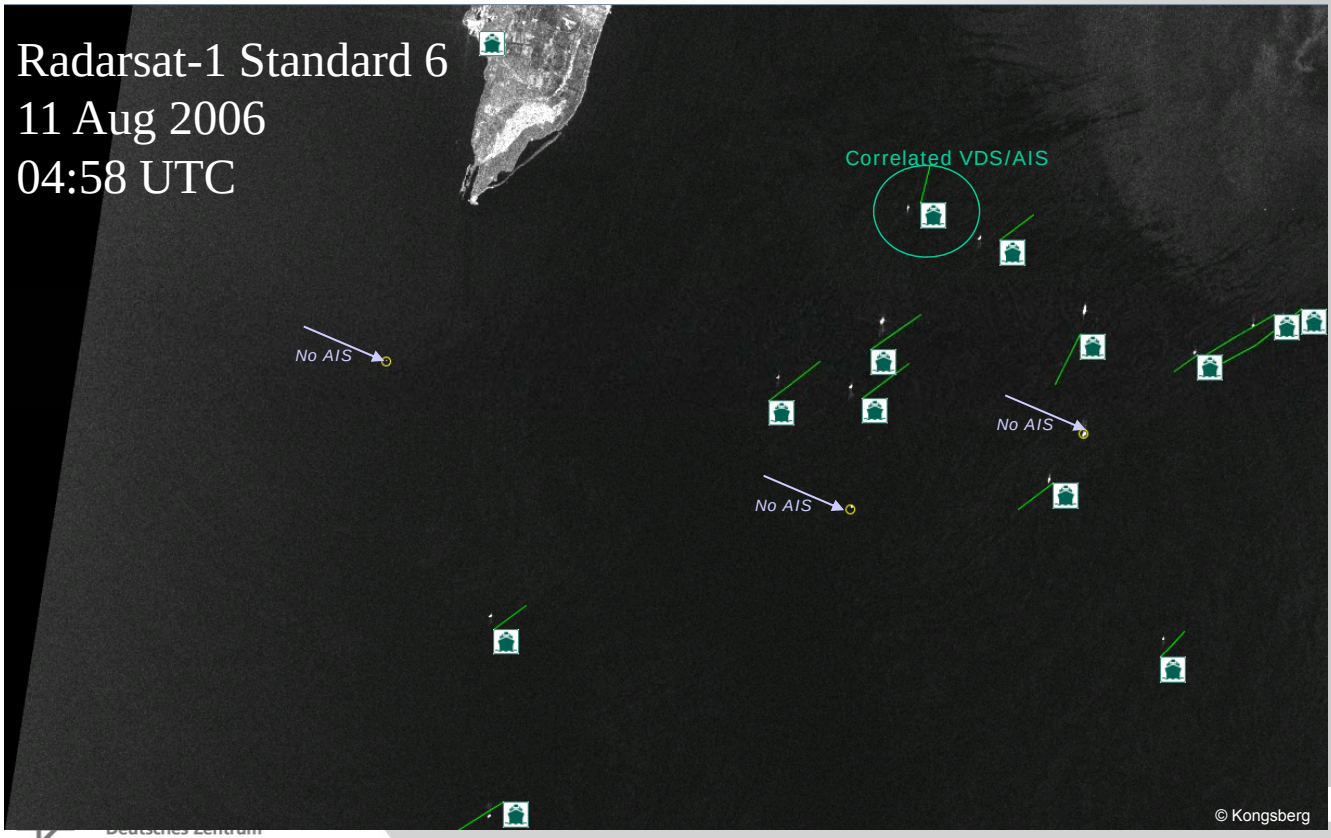
Current Status

- Ship Monitoring only in costal zones areas possible
  - **no global monitoring available**
  - **no global traffic coordination possible**
- Very limited technical equipment existing to track the ship traffic in open ocean areas to find out position and the vector of velocity (INMARSAT, VMS, ..)



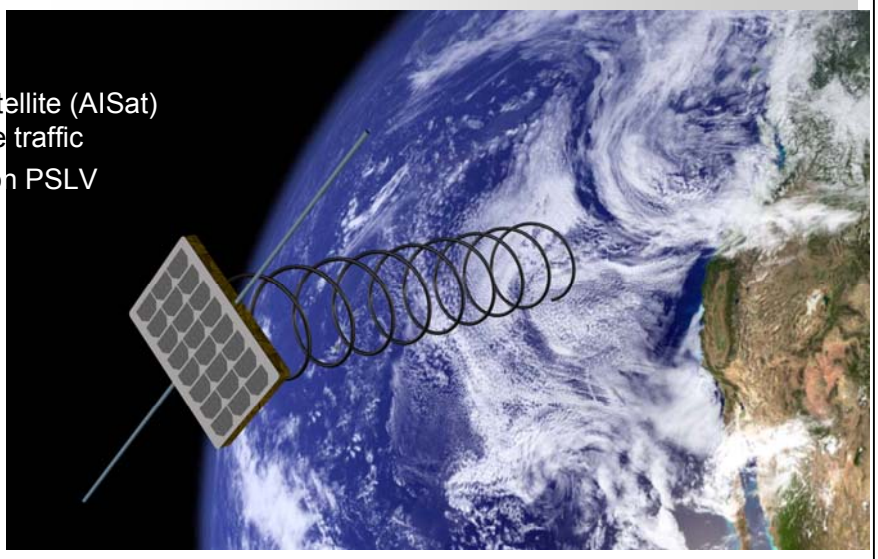
Example of Data fusion

DLR Study: Needs for on board classification and feature based data fusion

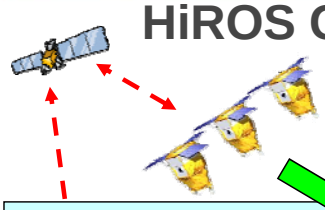


Optional Payload AIS DLR Micro Sat. Mission

- Small Payload with high additional information ships for larger Systems
  - Receiver: Mass less 1kg, Dimensions: 170 x 250 x 50 mm
  - Antenna: Helix
- **DLR-RY Pre Curser** Activities
  - Development of a nano satellite (AISat) for global Monitoring of see traffic
  - Planed Launch **1Q/ 2010** on PSLV



HiROS Ground Segment - Overview



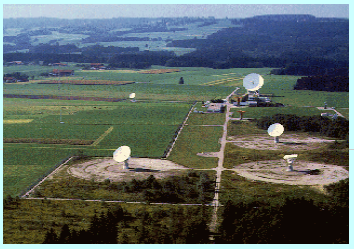
Tasking

HiROS-Data

Mobile Stations

DLR Realtime Processing Center Neustrelitz

DLR Ground Station Weilheim

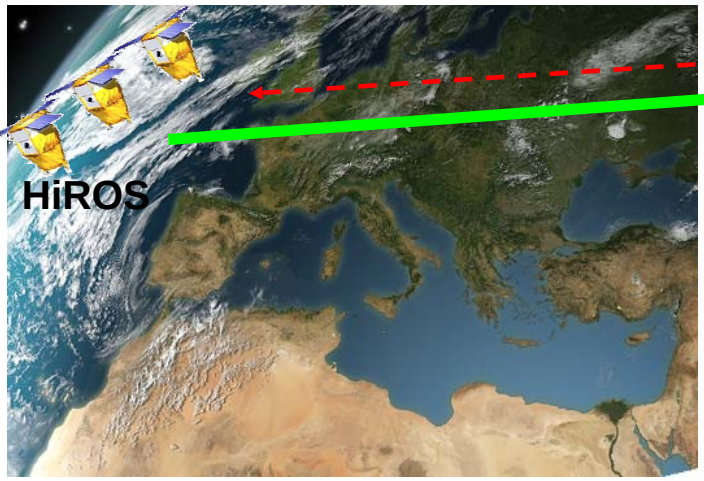


DLR Data Center

DLR Data Validation Center

DLR Control Center

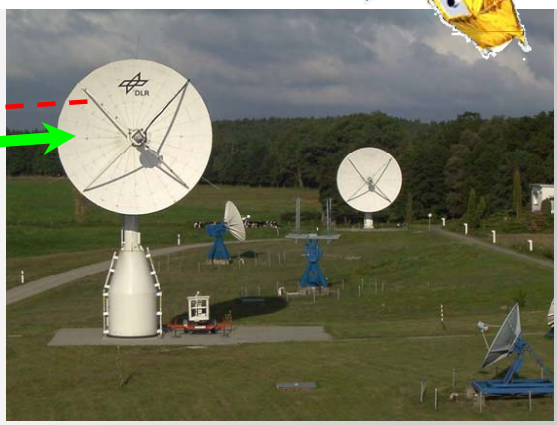
Ground Segment – Dataflow



HiROS

Tasking

HiROS-Data



Receiving and Processing

Users

Product Generation

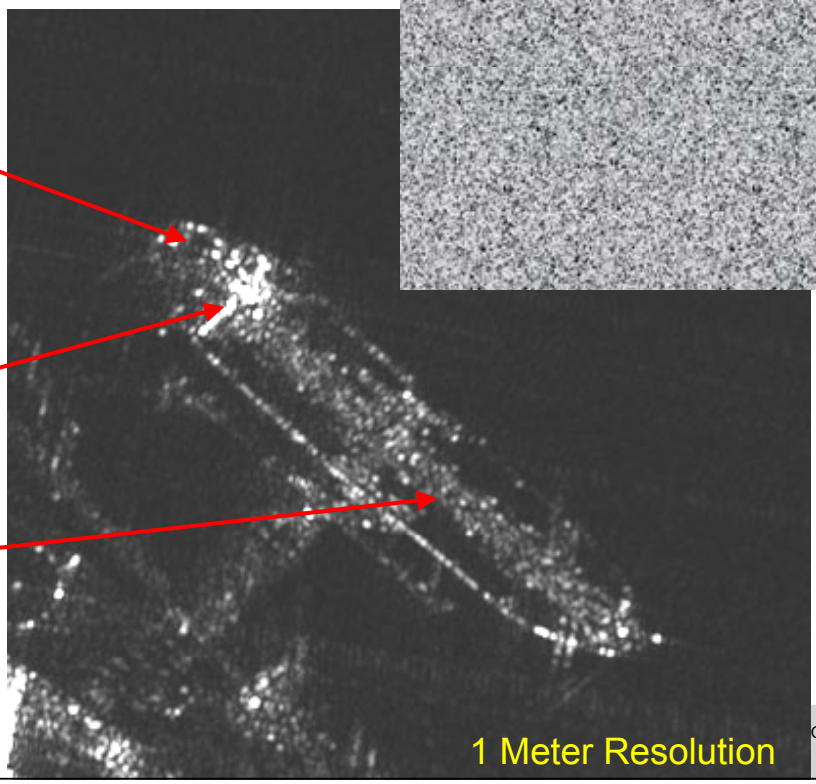
Realtime Delivery

Archiving

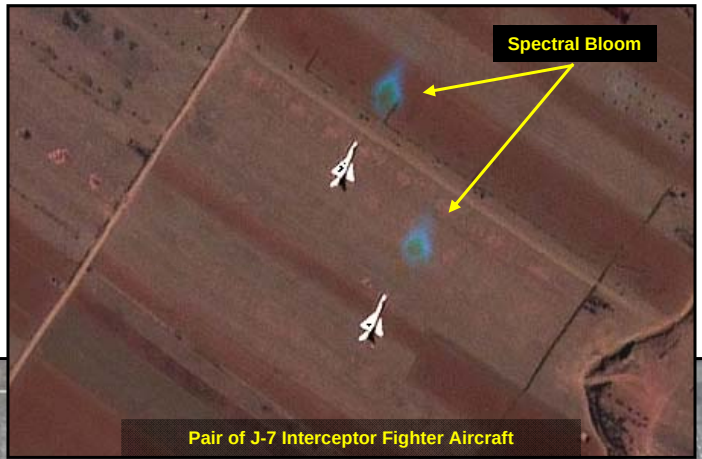
Catalogue

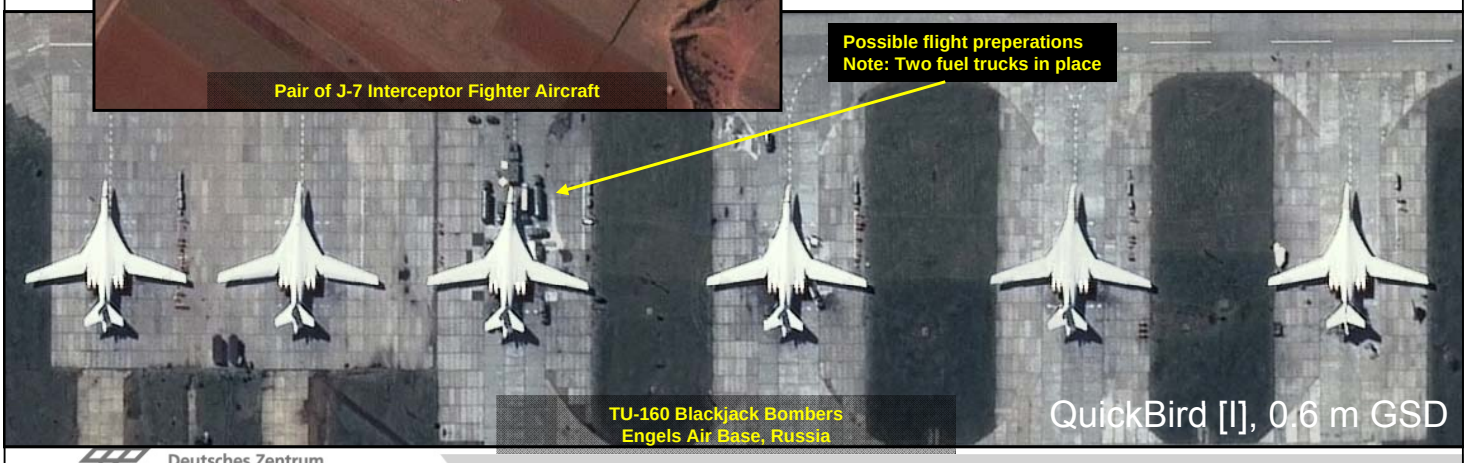
Detection Advantage of SAR Satellites

With Heavy Fog



Dual Use Applications





3D Images of Beijing (WV1, accuracy: x&y 50 cm, z 10 cm)

Status:
Change detection 3D HiROS data Product is 1 h after received data available

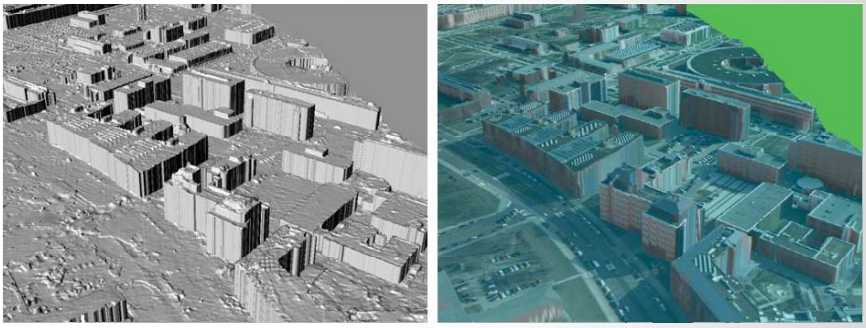
Goal (1):
Data processing at ground segment in real time

Goal (2):
Data processing on Board

Road Map

Why we are so optimistic regarding the real time solution?

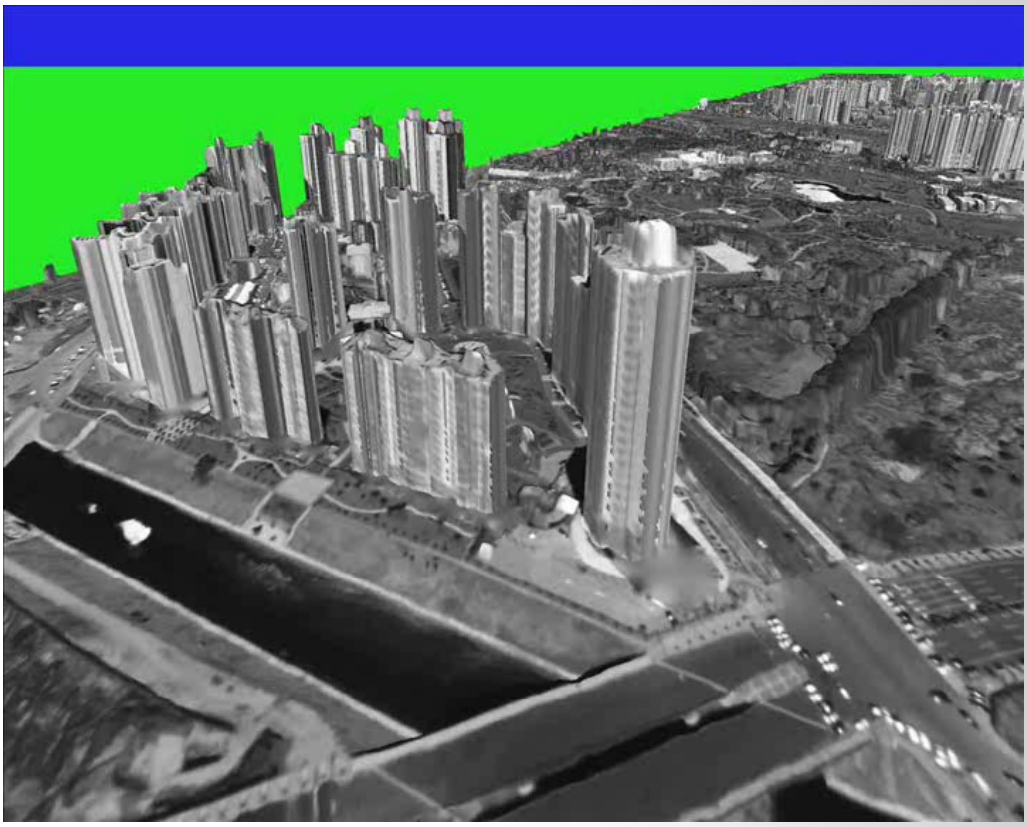
- Example: Airborne and Satellite data (MFC and WV)



- Example: Driver assistance systems

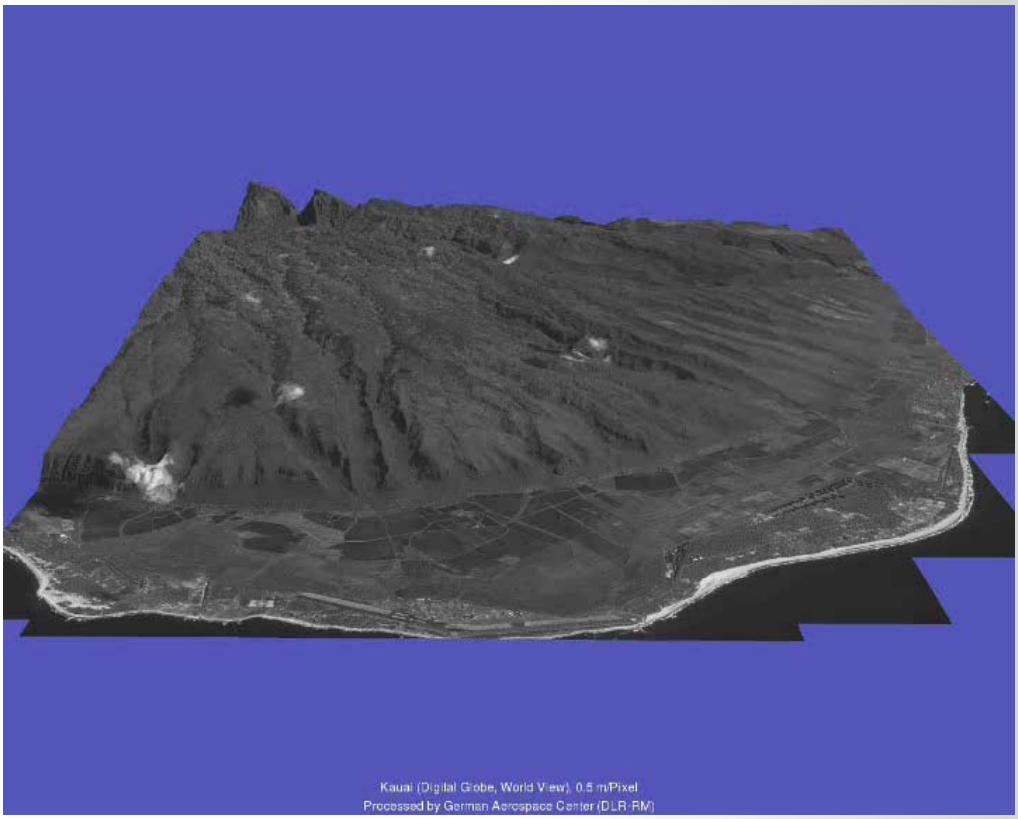
Same SGM algorithm by
1 k x 1 k stereo images 25 Hz
will be used 2011 in S-MB

3D Images with facade of Beijing (WV1, accuracy: x&y 50 cm, z 10cm)

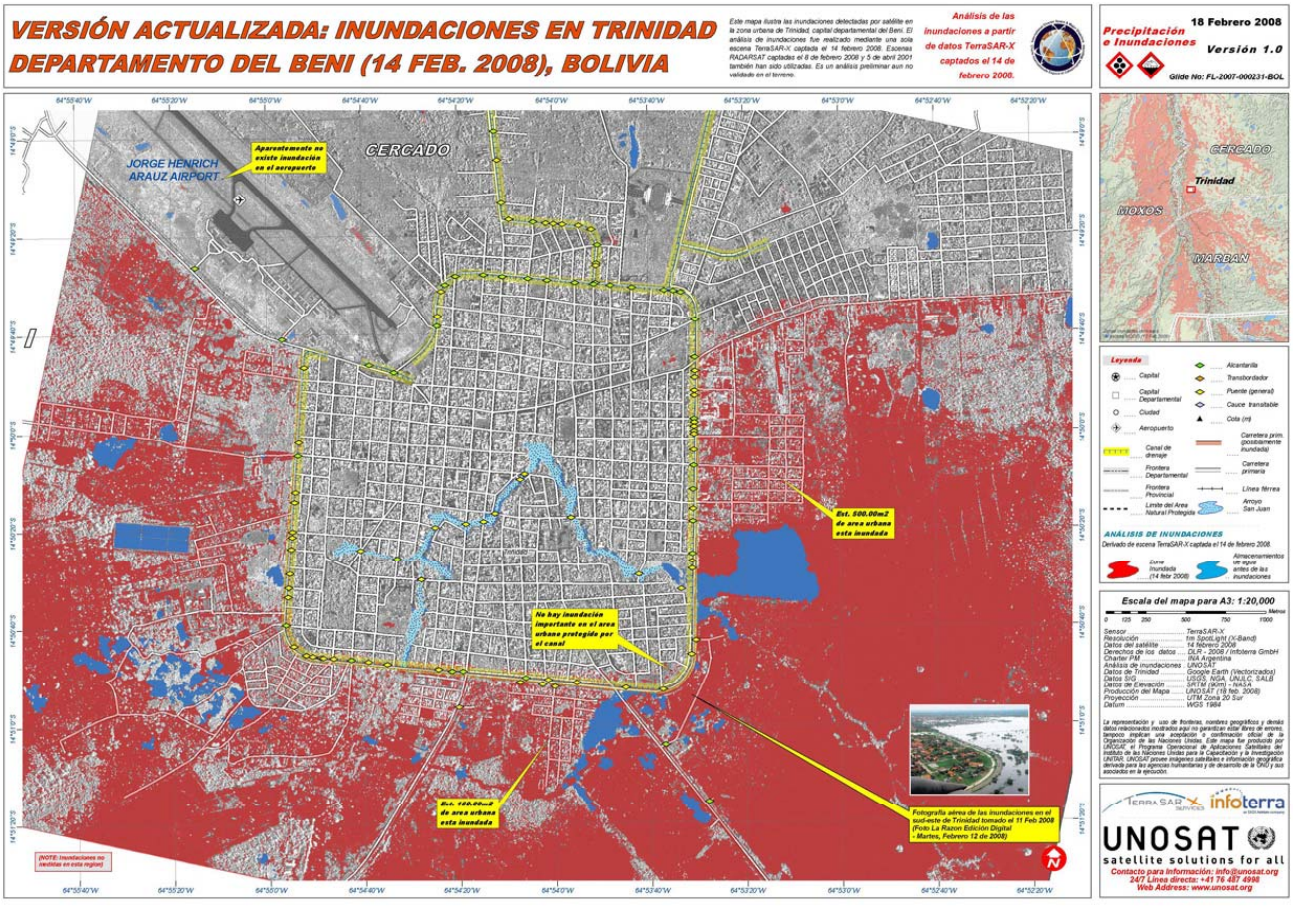


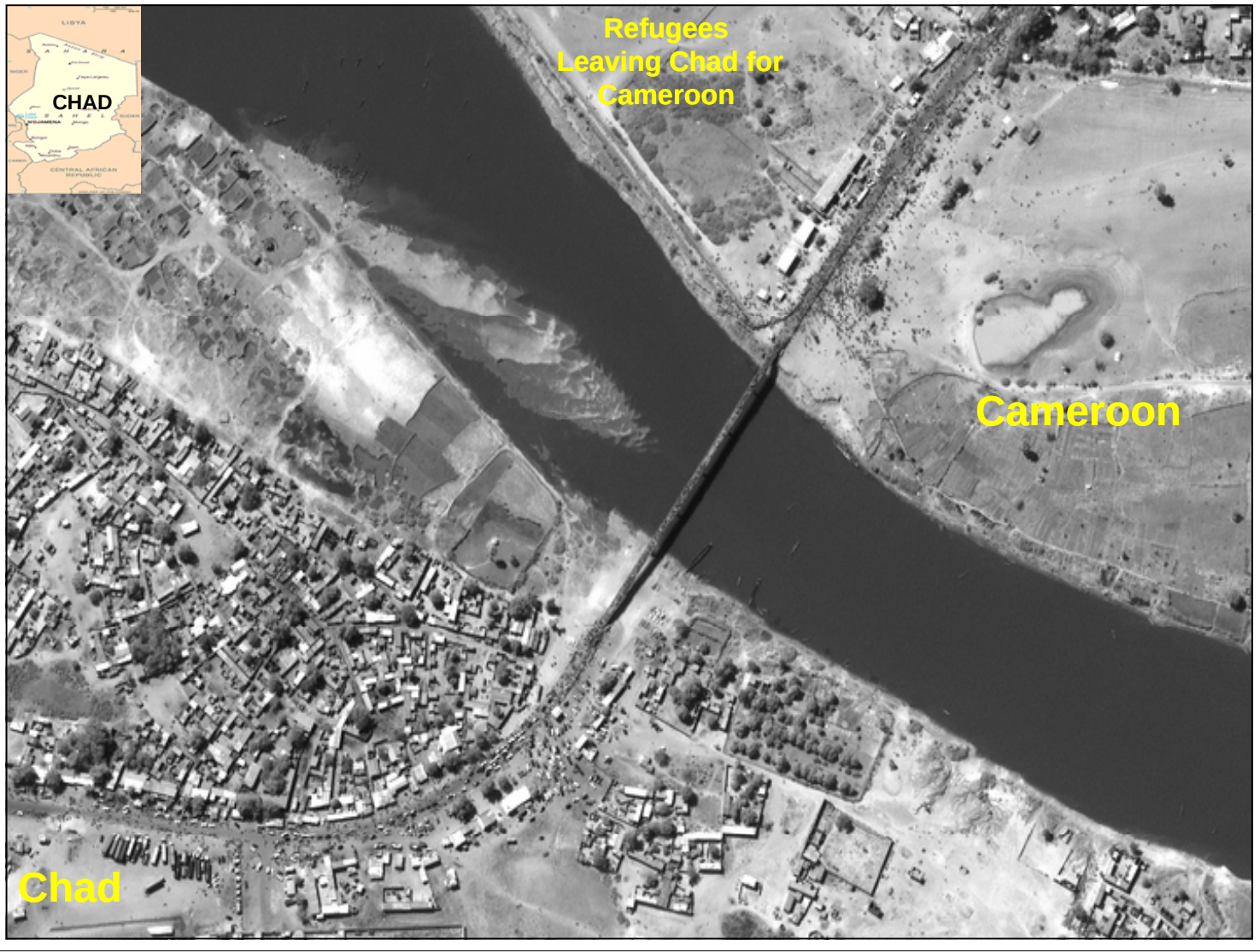
Las Vegas WV1 data 50 cm GSD (accuracy: x&y 50 cm, z 25cm)

Kauai, Island near Hawai, WV1 50 cm GSD (accuracy: x&y 50 cm, z 25cm)

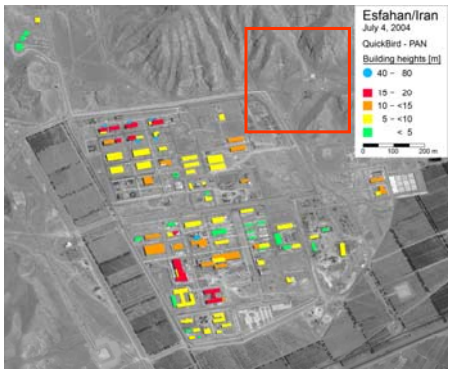


Optics/SAR for UN Emergency Response Flooding in Bolivia, Feb 2008



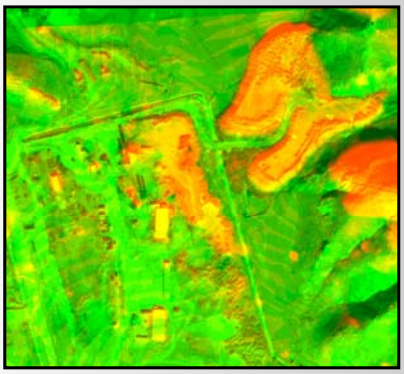

LIBYA
CHAD
CENTRAL AFRICAN REPUBLIC
Refugees
Leaving Chad for
Cameroon
Cameroon
Chad

HiROS Higher Level Data Products



Spaceborne DSM of 1 m accuracy from QuickBird

Processing



Changed DSM for analysis of under ground activities of the nuclear facilities in **Isfahan/Iran**

mass events

Automatic car detection Capabilities
Highways and traffic ways detection

Conclusion

1) Current digital airborne systems are working in a range of 5 cm – 1m GSD
2) Commercial satellites are working in a range 50 cm – 6.5 m GSD
3) HiROS constellation 24 h revisit time any area (10 Orbits: whole Germany ca. 3-5 days in 3D)
4) Minimal tasking 5-2 min before imaging (45 min standard, 5-2 min via patch antenna)
5) Fast data access 2 min after imaging via (Ka-Band) communication satellite
6) Processing time of 1000 km^2 in ca. 1 h (25 CPU's) near future real time
7) MR and HR satellite systems could not be used because of current law
8) System life time between 5 and 10 years
9) Data fusion between airborne / UAV systems of 1-25 cm GSD, radar and high resolution optical satellites for local and global applications

Today and in the near future space- and airborne / UAV systems are complementary

Data fusion product of airborne and terrestrial Sensors

Data fusion of airborne camera, LIDAR and panoramic camera
Accuracy x, y, z better 5 cm ➔ Geo 3D VR
Application Goal:
sensor systems space- **global 50 cm [GSD]** and airborne **local 1-25 cm [GSD]**