

# **DLR FireBIRD Mission - Technology Mission and Precursor Mission for Detection and Quantification of Wildfires**

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Knowledge for Tomorrow

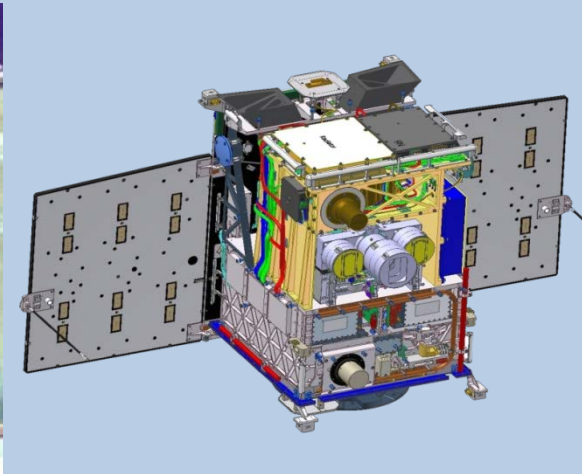


# FireBird Motivation and Heritage:

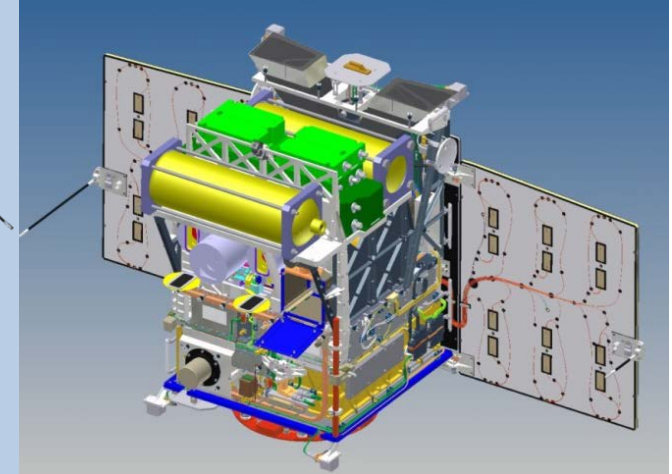
## from BIRD via TET-1 to BIROS satellite



BIRD (2001-2004 [2014])



TET-1 (2012- ?)



BIROS (2016- ?)

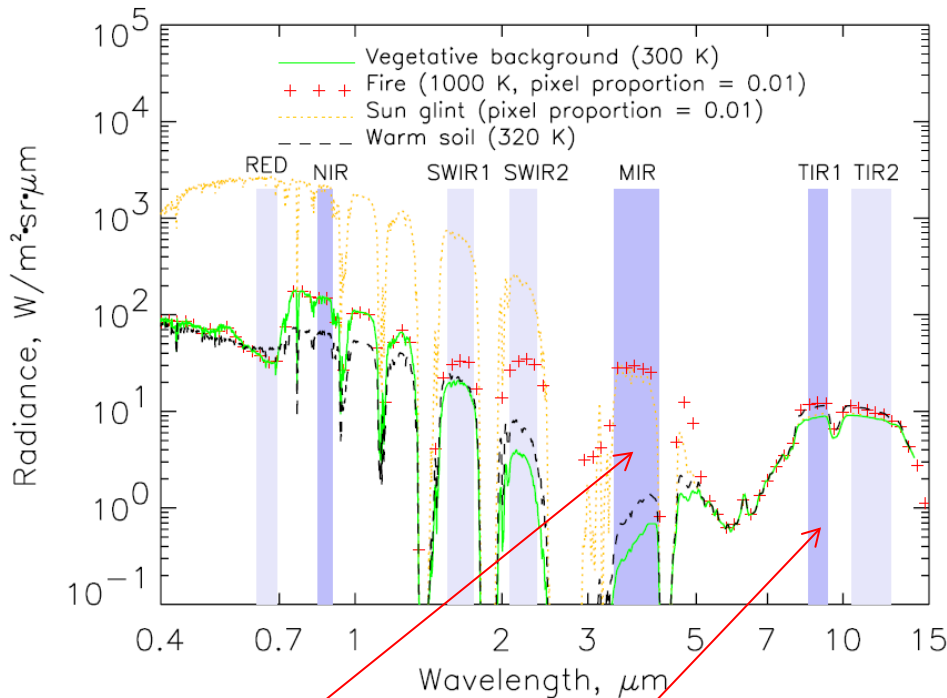
Design Philosophy: see

- „ **Cost Effective Earth Observation Missions**” ( R. Sandau et al, 2006)
- “**Affordable-Space -Missions**“(L.Fröbel et al, DLR 2004)
- “**BIRDTECH**” (ESA Contract Ref No: 3471983 , 2005)

{...Uses similar: bus-  
concepts, teams, ground  
facilities, test strategies...}



# Fire Detection and Estimation - Theoretical Background



**Fire Detection !**  
**Background Signature**

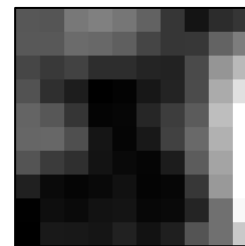
## Planck's law

$$L_{BB}(\lambda, T) = \frac{2hc^2}{\lambda^5} \left( \frac{1}{e^{\frac{hc}{\lambda kT}} - 1} \right)$$

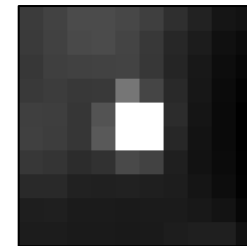
Perfect Emitter:  $L_{BB}$  [ $\text{Wm}^{-2}\text{m}^{-1}$ ]  
 Planck's constant:  $h$  [Js]  
 Boltzmann's constant:  $k$  [ $\text{Wm}^{-2}\text{K}^{-4}$ ]  
 Speed of the light in vacuum:  $c$  [ $\text{ms}^{-1}$ ]  
 Temperature:  $T$  [K]

## Wien's displacement law

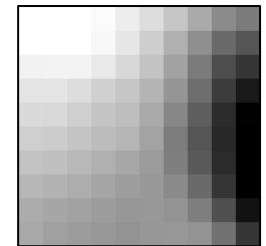
$$\lambda_{\max} = \frac{b}{T} \quad [\mu\text{m}] \quad \text{Wien's displacement constant: } b \approx 2900 \mu\text{m K}$$



VIS Red  
0.645  $\mu\text{m}$



MWIR  
3.825  $\mu\text{m}$



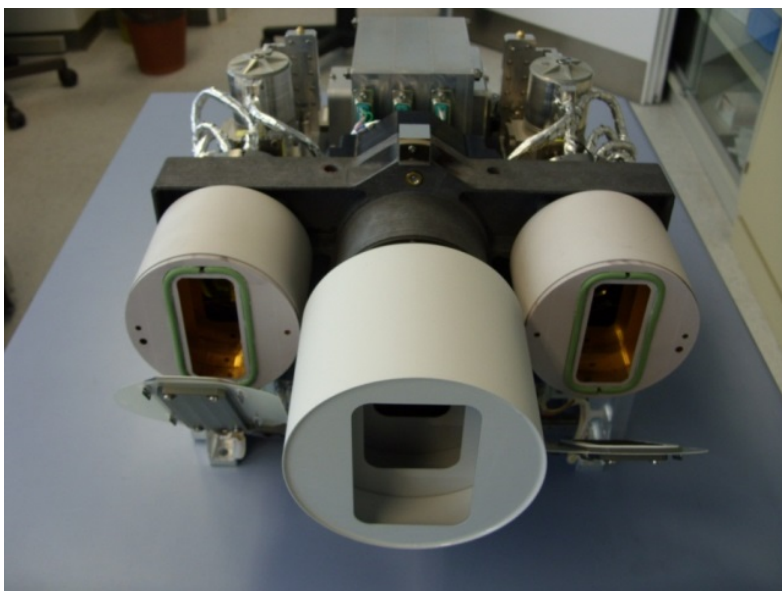
LWIR  
8.90  $\mu\text{m}$

Zhukov, B., Lorenz, E., Oertel, D., Wooster, M., Roberts, G.: Experience of detection and quantitative characterization of fires during the experimental small satellite mission BIRD. DLR-Forschungsbericht 2005-04 (2005).- p. 96.



# FireBIRD Multispectral Camera Payload

- IR-Camera:
  - Staggered lines
  - Black-Body for In-Flight Calibration
  - Dwell time 20 ms,
  - Integration time 4 ms and 2.7 ms for hot areas on demand
- VIS Camera synchronized with IR camera



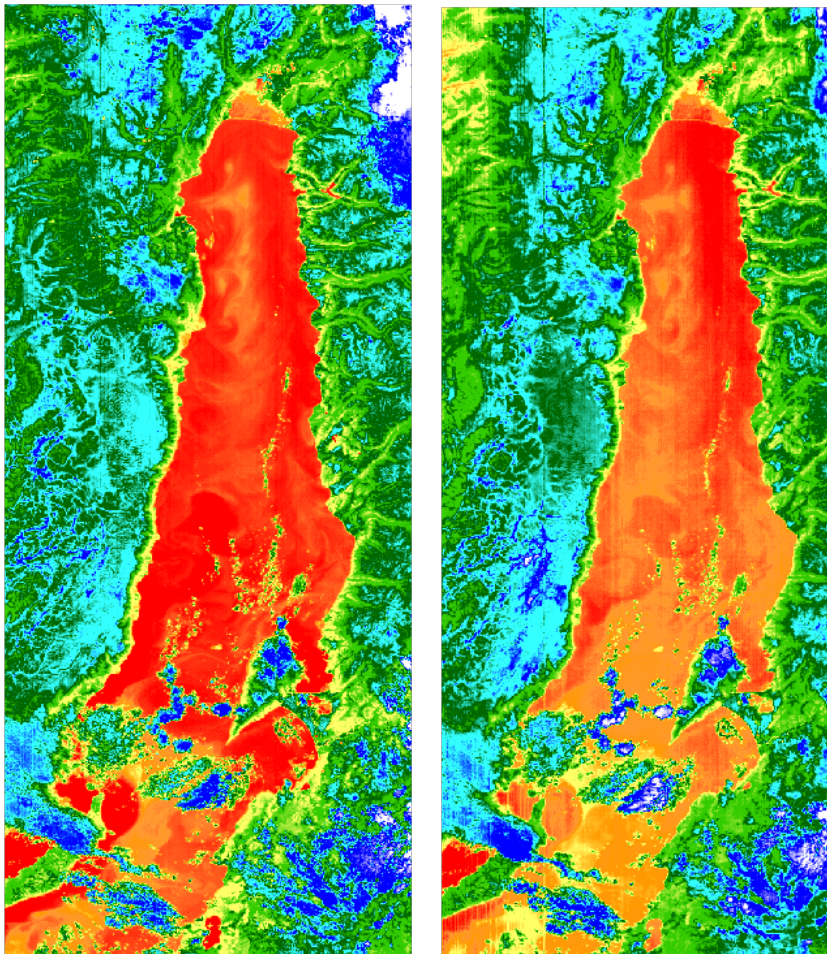
	<b>3 line-VIS Camera (3 line FPA, 6 ° separated )</b>	<b>2 Infrared- Cameras (staggered lines)</b>
<b>Wave length</b>	1 460 - 560 nm 2 565 - 725 nm 3 790 - 930 nm	MWIR: 3,4 - 4,2 µm LWIR: 8,5-9,3 µm
<b>Detector</b>	CCD- Zeile	CdHgTe Arrays
<b>Detector cooling</b>	Passive, 20 ° C	Stirling, 80 - 100 K
<b>Pixel size</b>	7 µm x 7 µm	30 µm x 30 µm
<b>Number of Pixel</b>	3 x 5164 (1250)	2 x 512 staggered
<b>Quantization</b>	14 bit	14 bit
<b>Ground resolution</b>	42,4 m 2)	356 m 2)
<b>Ground sampling distance</b>	42,4 m 2)	178 m 2)
<b>Swath width</b>	211 km 2)	178 km 2)
<b>Accuracy</b>	100m on ground	100m on ground
<b>Main FireBird camera parameters <sup>2)</sup> Altitude 510km</b>		



# Fire Detection & Lake Surface Temperature

## Lake Baikal 13.09.2017 13:00 UTC

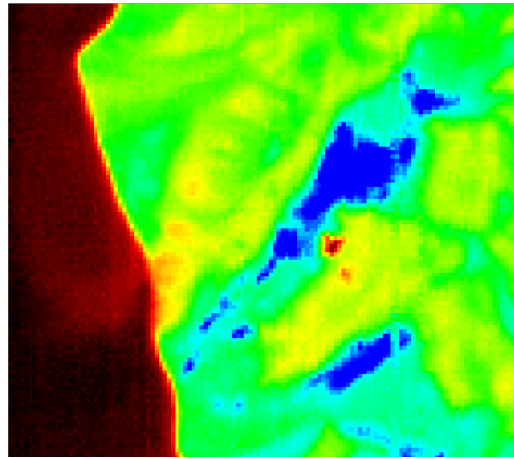
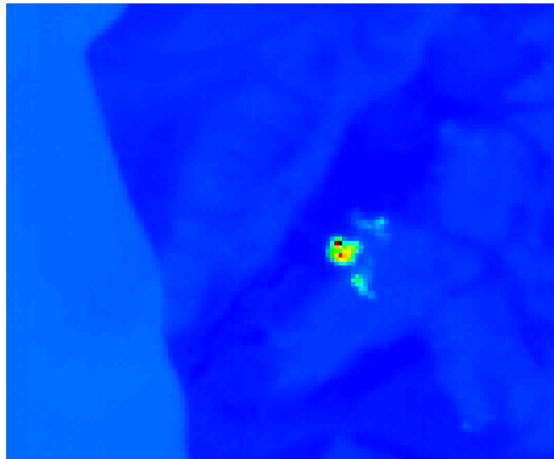
- Atmospheric temperature from night scene
  - MWIR 3.85  $\mu\text{m}$  (left)
  - LWIR 8.9 $\mu\text{m}$  (right)
- fixed atmospheric correction has errors of  $\approx 3\text{K}$
- Improvement possible by use of Optimal Estimation Algorithm in combination with meteorological data is needed



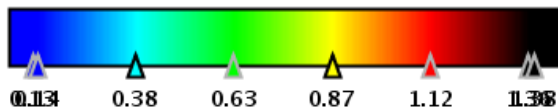
BrightnessTemperature\_MWIR [-]



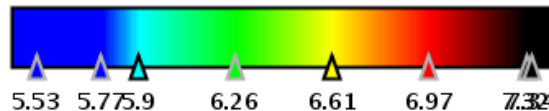
# Forest Fire – a small example



MWIR [-]



LWIR [-]



## Fire parameter

Cluster Size	FRP (MW)	T <sub>min</sub> (K)	T (K)	T <sub>max</sub> (K)	A <sub>min</sub> (m <sup>2</sup> )	A (m <sup>2</sup> )	A <sub>max</sub> (m <sup>2</sup> )
40	33	460	502	586	3098	9190	18230
8	3	500	531	577	340	603	936

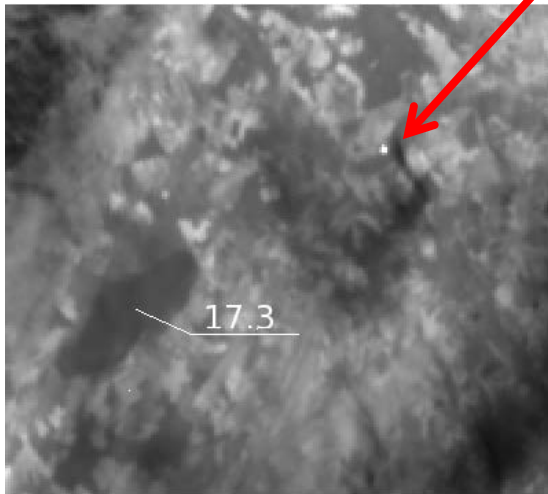
## Fire detection algorithm (B. Zhukov)

1. Detection of Anomalies
2. Screening of background
  - Clouds
  - Sun Glint
  - Warm surfaces
3. Determination of background temperature
4. Hot pixel detection
5. Cluster consolidation
6. Parameter estimation
  - Coordinates
  - Temperature
  - Effective Fire Area
  - Fire Release Power



# Validation of fire parameter estimation

- Error in FRP within 35 % relative to ground data
- $T_F$  and  $A_F$  within estimated margins
- Inhomogeneous background accounts for largest error
- Lake temperature
  - estimated: 17.3 °C
  - measured: 21.4 °C



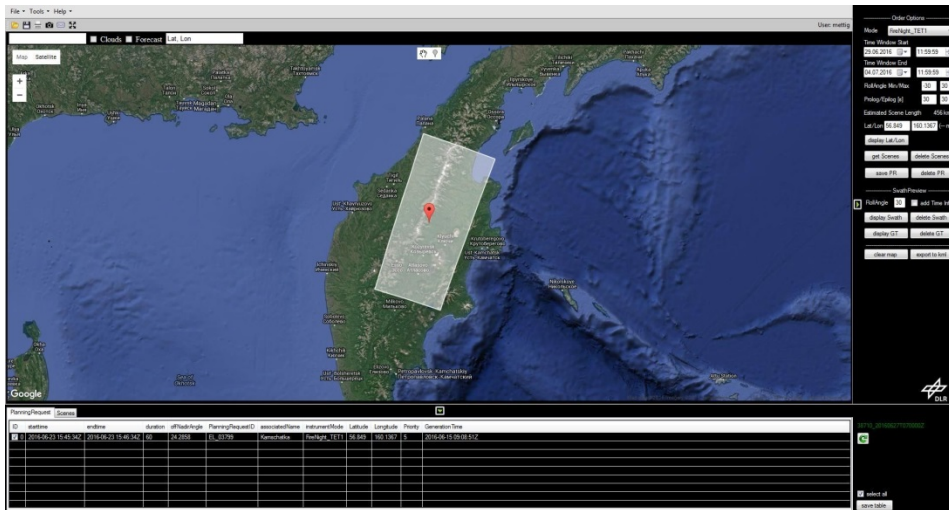
	Savannah Shabeni			Savannah Skukuza 6 Plot			Experimental Fire DEMMIN / Germany		
	TET-1	Helicopter	Ratio	TET-1	Helicopter	Ratio	TET-1	Ground	Ratio
$T_{min} / K$	661	550		559	550		490		
$T_{mean} / K$	685	668	1,02	580	595	0,97	727	940	0,77
$T_{max} / K$	713	907		606	803		1500	1150	
$AF_{min} / ha$	0,15			0,36			0,001		
$AF / ha$	0,19	0,24	0,80	0,47	0,60	0,79	0,0141	0,0143	0,99
$AF_{max} / ha$	0,23			0,60			0,173		
$FRP / MW$	23,6	35,1	0,67	30,3	25,5	1,19	2,24	1,36	1,65
$FRP / kW / m^2$	12,48	14,80		6,43	4,27		15,85	9,51	

T - Effective fire temperature; AF - Effective Fire Area; FRP – Fire Radiative Power (Helicopter based data still pre-liminary. Source: Paugam, R., Wooster, M., KCL)

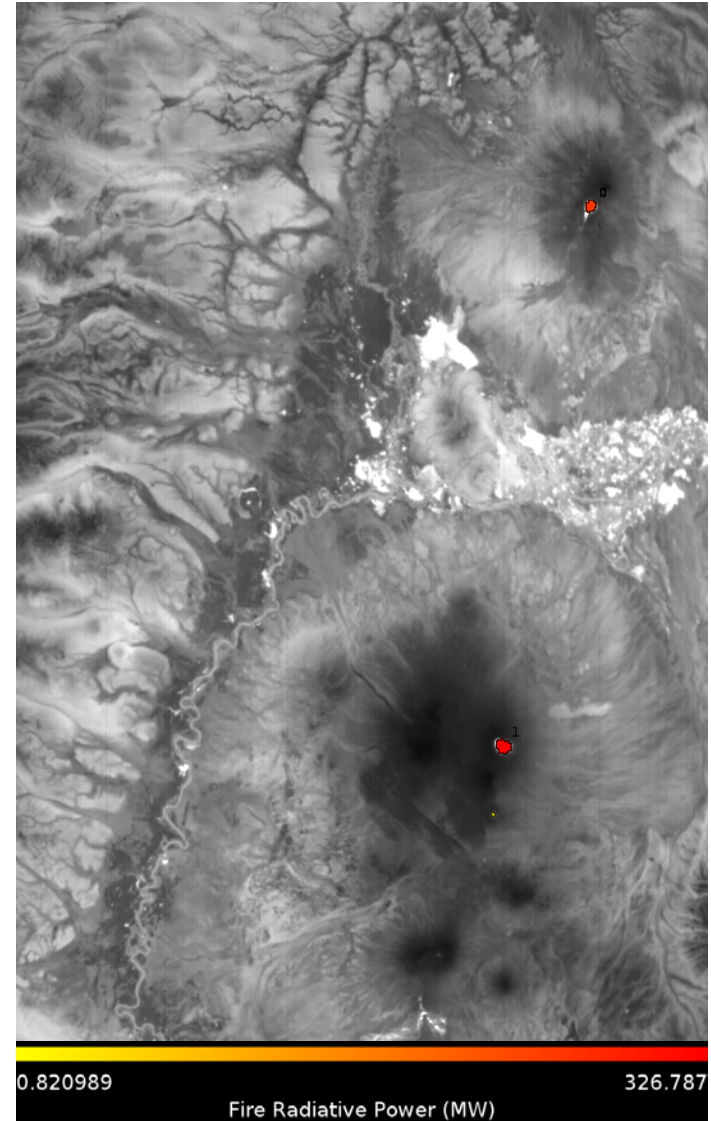


# Volcanoes

## Kamchatka 23.06.2016

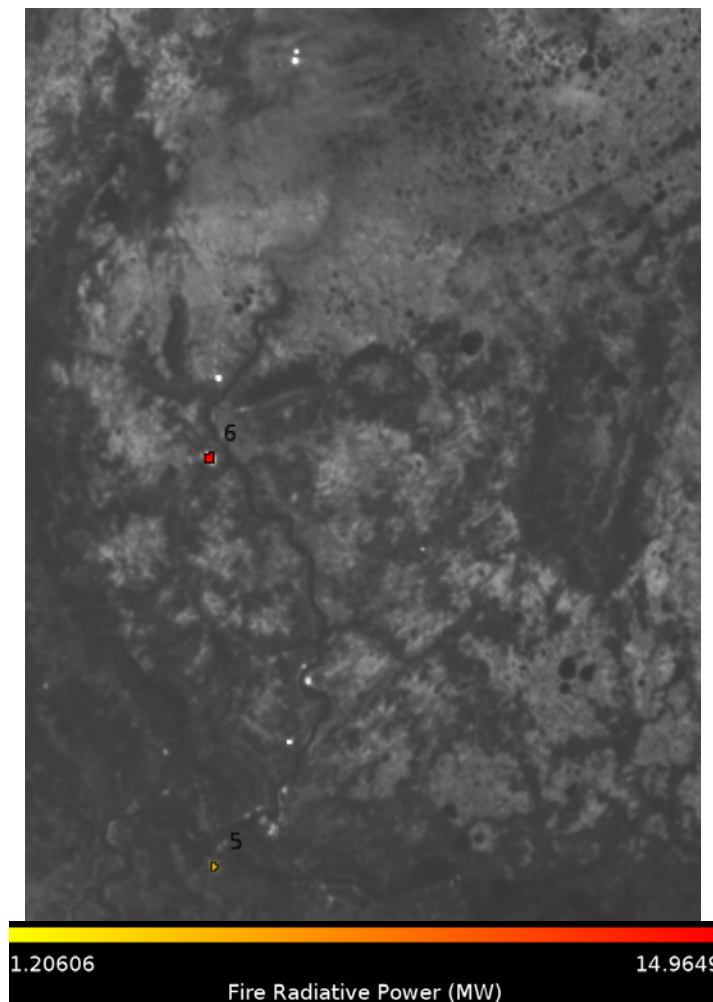


Cluster Size	FRP (MW)	T_min (K)	T_max T (K)	A_min (m^2)	A (m^2)	A_max (m^2)
46	<b>83</b>	474	486	500	39820	49660 60363
85	<b>84</b>	755	766	778	15467	16710 17995



# Gas Flaring Estimation

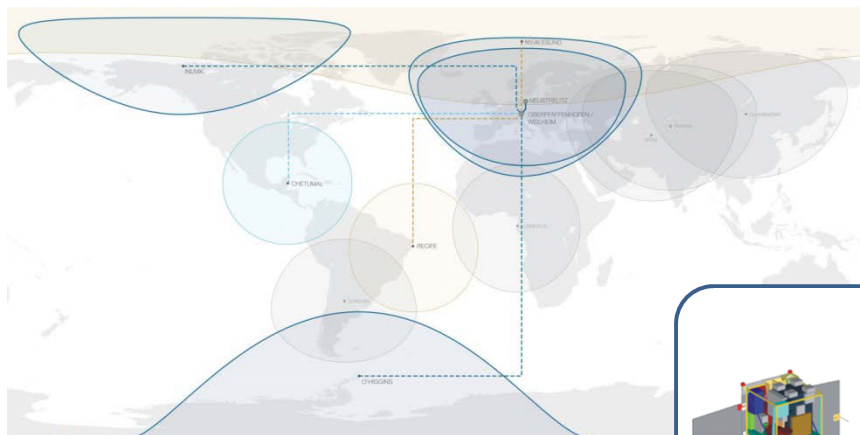
- So far based on visible light
- No quantities in terms of power and therefore CO<sub>2</sub>
- Results show that fire algorithm (with lowered thresholds) provides quantities
- Possibly longer integration time needed



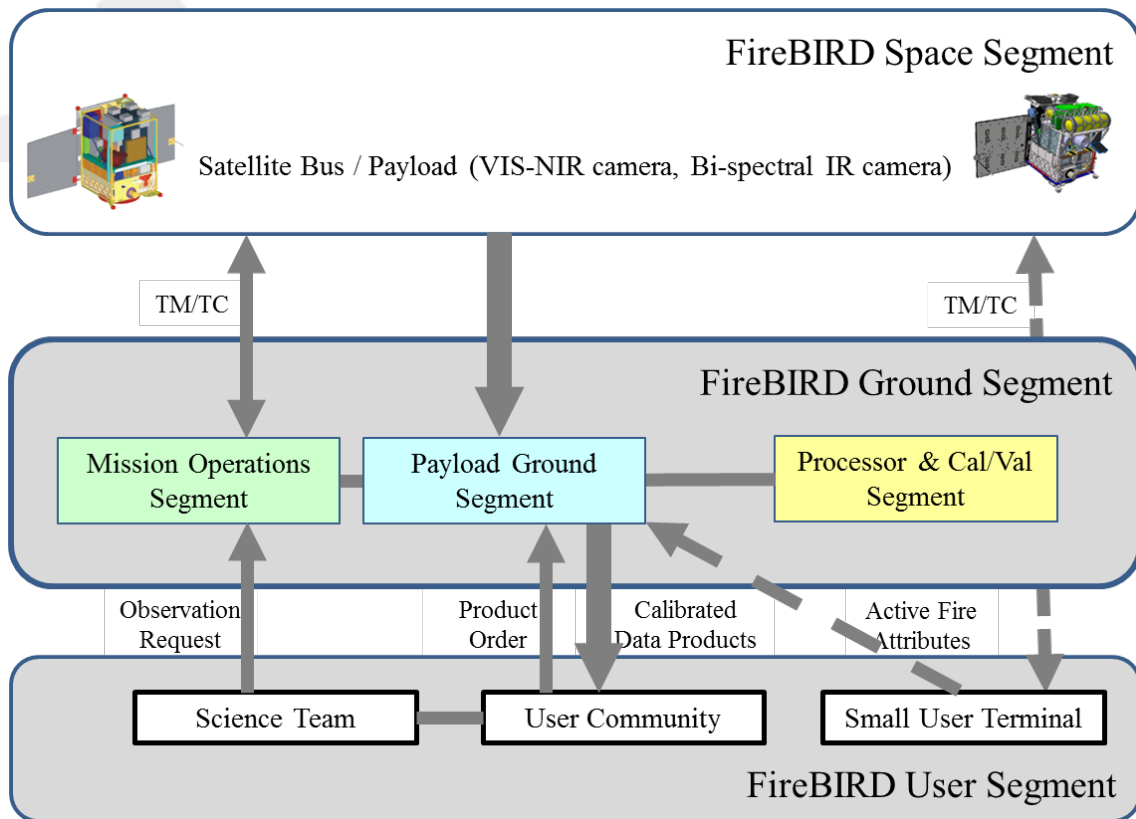
- Energy released by gas flare in Novy Urengoy in a night time image of the MWIR band on 23. July 2016
- Up to 15 MW



# Up- and Downlink and Data Processing



- Data reception at DLR Ground Station Network and collection in Neustrelitz
- Operational Near-Real Time Processing (25 min) to L1B and L2 Fire Products
- Delivery via FTP



# Data Archiving and Distribution

## Ordering

- Products are free available
- Registering as science user

## Product Content

- Geoannotated Spectral Radiances L1b
- Coregistered Spectral Radiances L2a
- Thematic Fire Products

## Product formats

- HDF5
- ENVI + ASCII

Special Products for Crisis Information (DLR-ZKI)

The screenshot shows the EOWEB Earth Observation Center interface. The top navigation bar includes 'Earth Observation Center', 'Home', 'Imprint', and 'Contact'. The user is logged in as 'asfrauenberger'. The main interface is divided into a left sidebar and a main content area. The sidebar contains a 'Shop Cart' and 'Order Monitoring' section with a 'Catalogue' of products. The 'Collections' section is expanded to show 'FireBIRD' and 'FBLMSC.L0'. The 'Query Mode' is set to 'Standard'. The 'Date' range is from '2016-01-01 00:00:00' to '2016-12-31 23:59:59'. The 'Area' is defined by a rectangle with 'Center Lat/Lon' at 56.975, 96.922 and 'Extension Lat/Lon' at 35.899, 143.516. The main content area displays a map of Russia with several red and green rectangular annotations. Below the map is a table of search results with 11 columns: Id, Avail., Abstract, Item Type, Mission/Satellite, Sensor, Start Date, End Date, and Cloud Co. The table shows 11 records, with the first record selected.

Id	Avail.	Abstract	Item Type	Mission/Satellite	Sensor	Start Date	End Date	Cloud Co
21	●	FBI MSC.L0	CatalogueSci...	FBI	MSC	2016-09-08T19:15:59.0	2016-09-08T19:17:08.2	-1
22	●	FBI MSC.L0	CatalogueSci...	FBI	MSC	2016-09-08T20:51:18.0	2016-09-08T20:52:57.2	-1
23	●	FBI MSC.L0	CatalogueSci...	FBI	MSC	2016-09-11T18:55:04.0	2016-09-11T18:56:13.2	-1
24	●	FBI MSC.L0	CatalogueSci...	FBI	MSC	2016-09-11T09:09:03.0	2016-09-11T09:10:17.2	-1
25	●	FBI MSC.L0	CatalogueSci...	FBI	MSC	2016-09-11T22:01:20.0	2016-09-11T22:02:28.2	-1
26	●	FBI MSC.L0	CatalogueSci...	FBI	MSC	2016-09-13T04:43:07.0	2016-09-13T04:44:51.3	-1
27	●	FBI MSC.L0	CatalogueSci...	FBI	MSC	2016-09-13T19:05:43.0	2016-09-13T19:08:02.2	-1
28	●	FBI MSC.L0	CatalogueSci...	FBI	MSC	2016-09-17T22:48:10.0	2016-09-17T22:49:19.2	-1
29	●	FBI MSC.L0	CatalogueSci...	FBI	MSC	2016-09-18T22:09:19.0	2016-09-18T22:10:28.2	-1
30	●	FBI MSC.L0	CatalogueSci...	FBI	MSC	2016-09-24T10:02:40.0	2016-09-24T10:03:32.5	-1
31	●	FBI MSC.L0	CatalogueSci...	FBI	MSC	2016-09-25T22:16:21.0	2016-09-25T22:17:30.2	-1
32	●	FBI MSC.L0	CatalogueSci...	FBI	MSC	2016-09-27T20:57:58.0	2016-09-27T20:59:37.2	-1

[www.eoweb.de](http://www.eoweb.de): Product search Russia summer 2016



## Conclusions

- Fire detection is successful
- Valuable for fire monitoring in remote areas, e. g. Russia
- Coverage is limited to 7 Scenes per day due to downlink capacity
- Future: On-board data processing is needed for
  - fast alerts
  - data reduction, e. g. cloud screening
- More users are welcome!

# Spacibo

