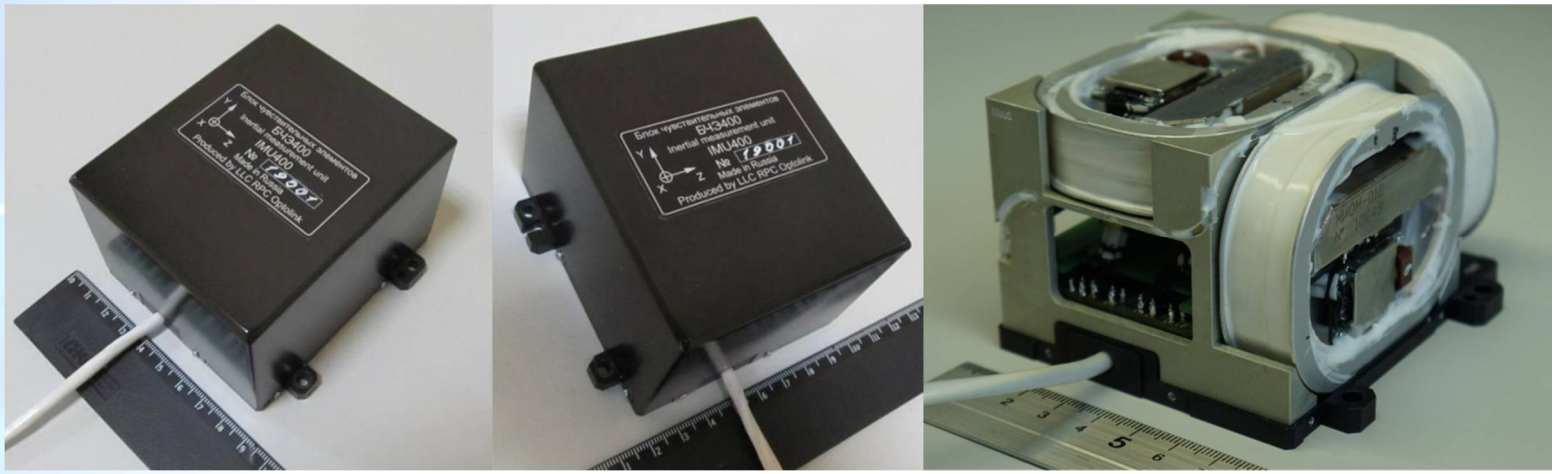
COMPACT NEAR-NAVIGATION-GRADE IFOG INERTIAL MEASUREMENT UNIT IMU400

Yu.N. Korkishko, V.A. Fedorov, S.V. Prilutskiy, D.V. Obuhovich, I.V. Fedorov,
V.E. Prilutskiy, V.G. Ponomarev, A.I. Zuev, V.K. Varnakov, I.V. Morev, S.M.Kostritskii

OPTOLINK RPC LLC, Moscow, Russia

FIBER OPTICAL SOLUTION
Fiber Optical Solution, Riga, Latvia



Outline:

1. Optolink's production capacities & premises
2. IMU400 c-SWaP & mechanical properties; accuracy & specs
3. MEMS accelerometers SF non-linearity & delay evaluation
4. IMU postprocessing results: gyrocompassing & static; track navigation
5. Conclusion

OPTOLINK

Inertial Sensors and Systems
Symposium Gyro Technology

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From optical components to navigation systems

LLC RPC «Optolink», Sosnovaya alley, d. 6A, building 5, module 3-1, Zelenograd, Moscow, 124489, Russian Federation
Telephone: +7(495) 663-17-60; Fax: +7(495) 663-17-61; Web-site: www.optolink.ru; E-mail: opto@optolink.ru

RPC LLC, Moscow, Russia

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1. Optolink's production capacities & premises

Headquarters

Moscow, Zelenograd

Development and production of **integrated optical circuits** on $LiNbO_3$, fiber-optic sensors and **inertial navigation systems**.

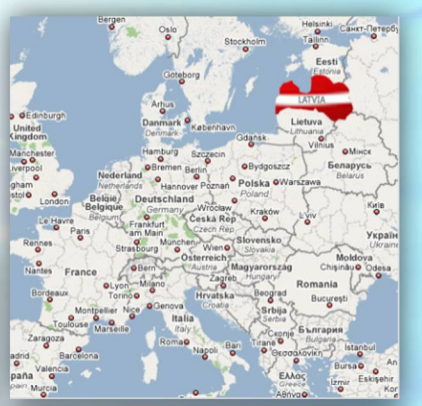
Arzamas branch

Production of **special optical fibers** (PM, spun, etc.) and components.

Saratov branch

Development and production of **fiber-optic gyroscopes** and sensors

Riga, Podraga 2



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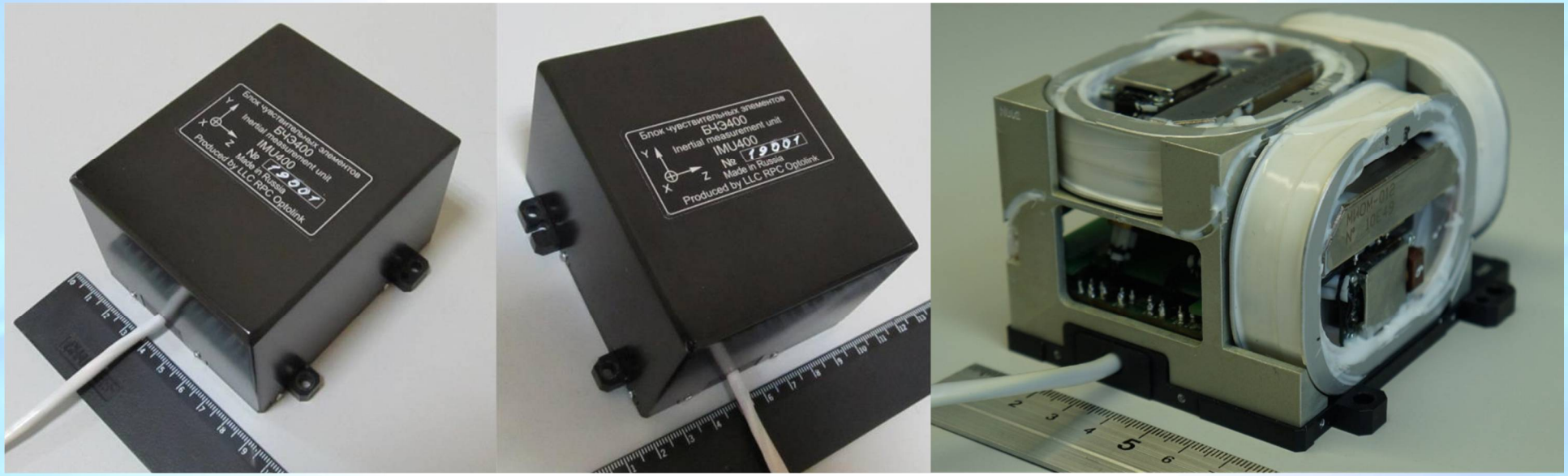
2a. IMU400 c-SWaP & mechanical properties



80×95×62 mm, 0.7 kg, 0.5 l, ≤7 W

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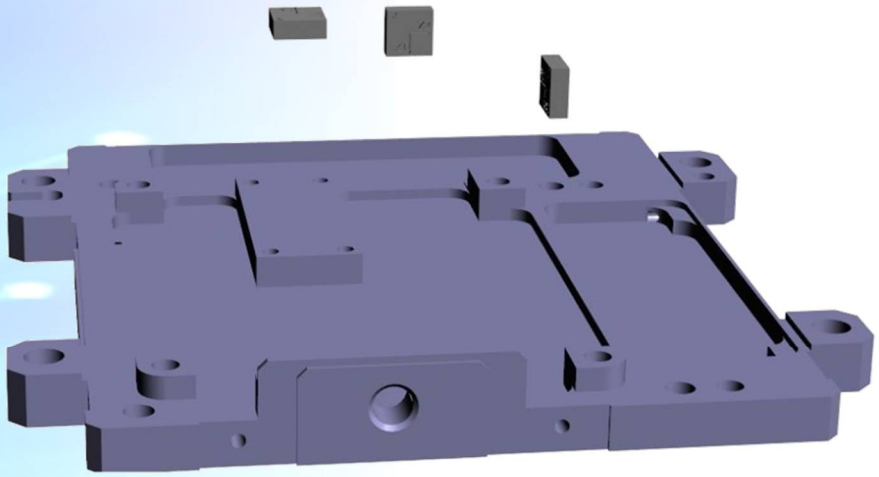
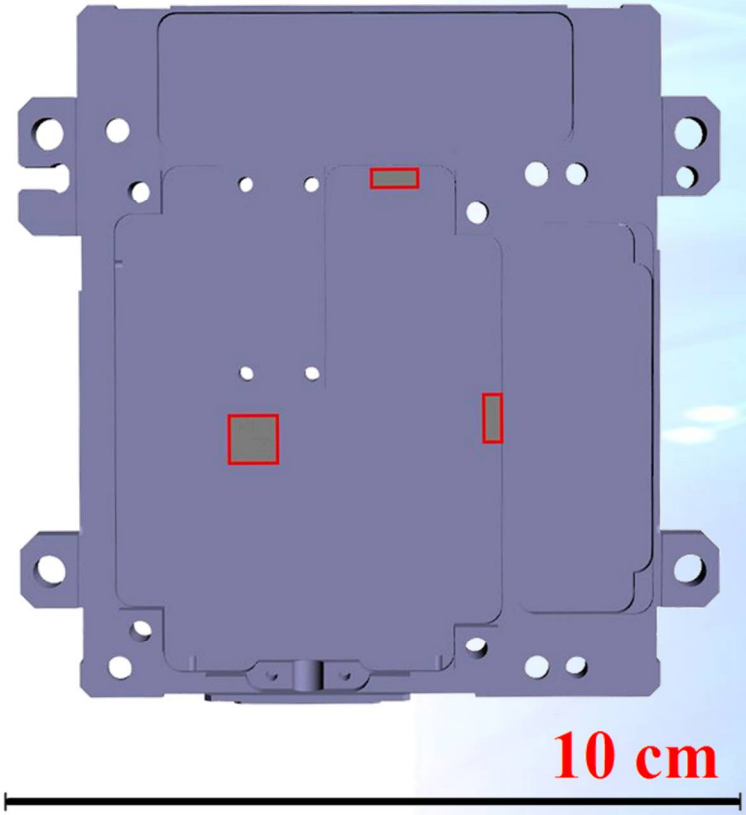
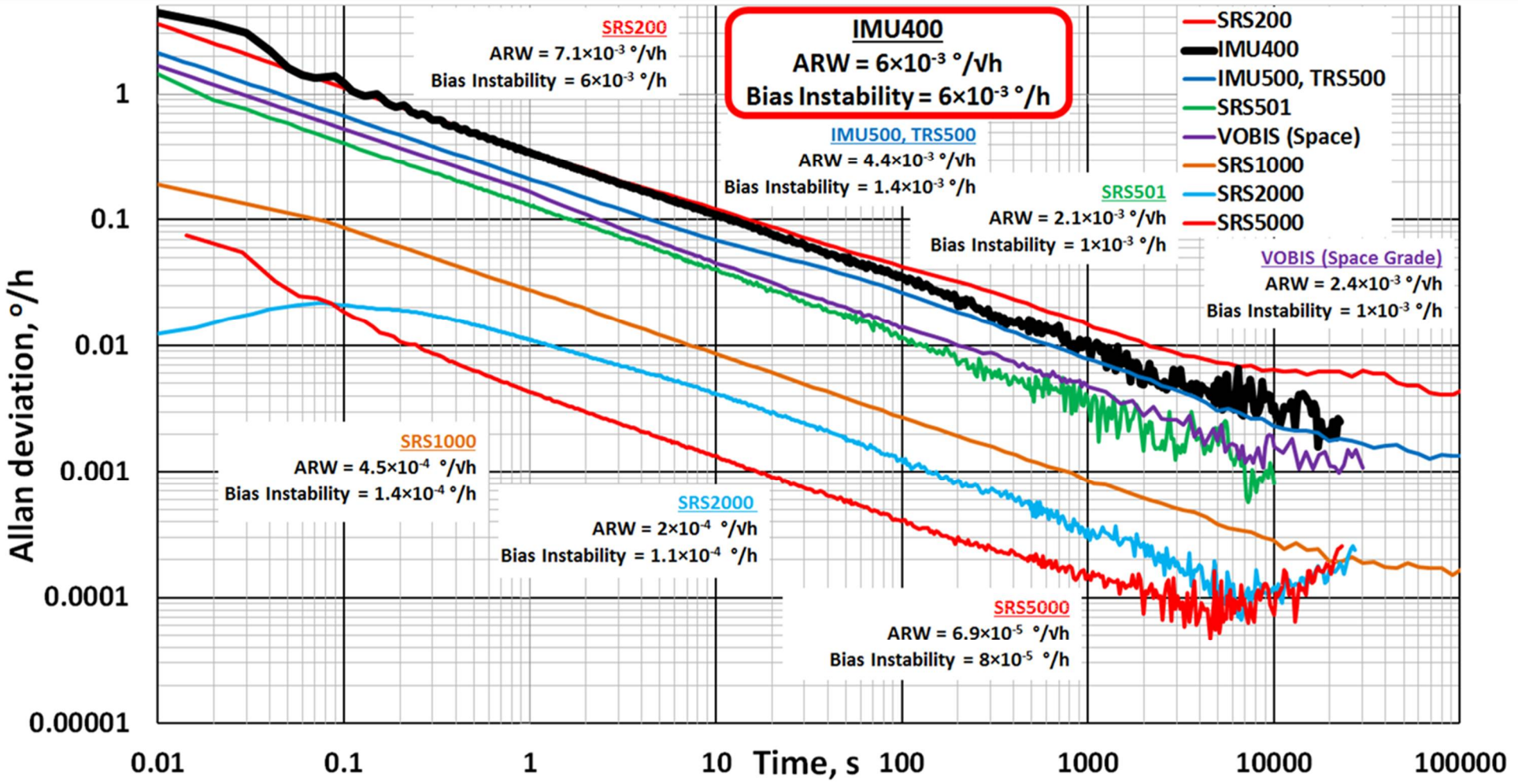




Spatial displacement of 3 physical MEMS-accelerometer triads inside the IMU400

2b. Sensors accuracy and specs



IMU400 Allan Variance plot in Optolink's FOG family

2b. Sensors accuracy and specs

Performance	IMU400
Gyro	
Angular rate range, °/s	±550
Bias drift at constant temperature (1σ, 100s-averaging), °/h	0.1
Bias drift (1σ, 100s-averaging) in operational temperature range, °/h	0.7 (*0.3)
Angle random walk, °/ √h	0.01
Scale factor error, ppm	500 (*200)
Bandwidth, Hz	> 1000

Accelerometers	
Range, g	±10
Bias drift at constant temperature, mg	1
Bias drift in operational temperature range, mg	1.0 (*0.4)
Scale factor error, ppm	500 (*300)
Noise power density, mg/ √Hz	0.08
Bandwidth, Hz	> 300
Physical Characteristics	
Misalignment, °	0.08 (*0.015)
Output sample rate, Hz	up to 2000
Power supply, V / Consumption, W	5 / 7
Digital output interface	RS-422
Operational temperature range, °C	-40 ~ +60
Dimensions, mm	80 × 95 × 62
Weight, kg	0.7

*precise calibration (optional)

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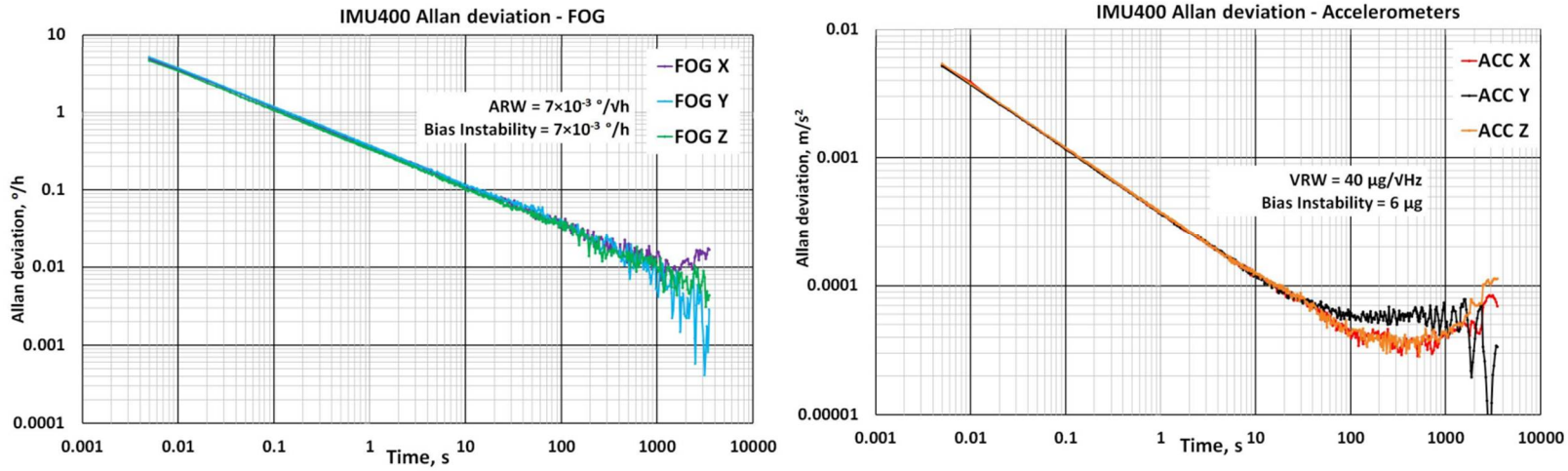
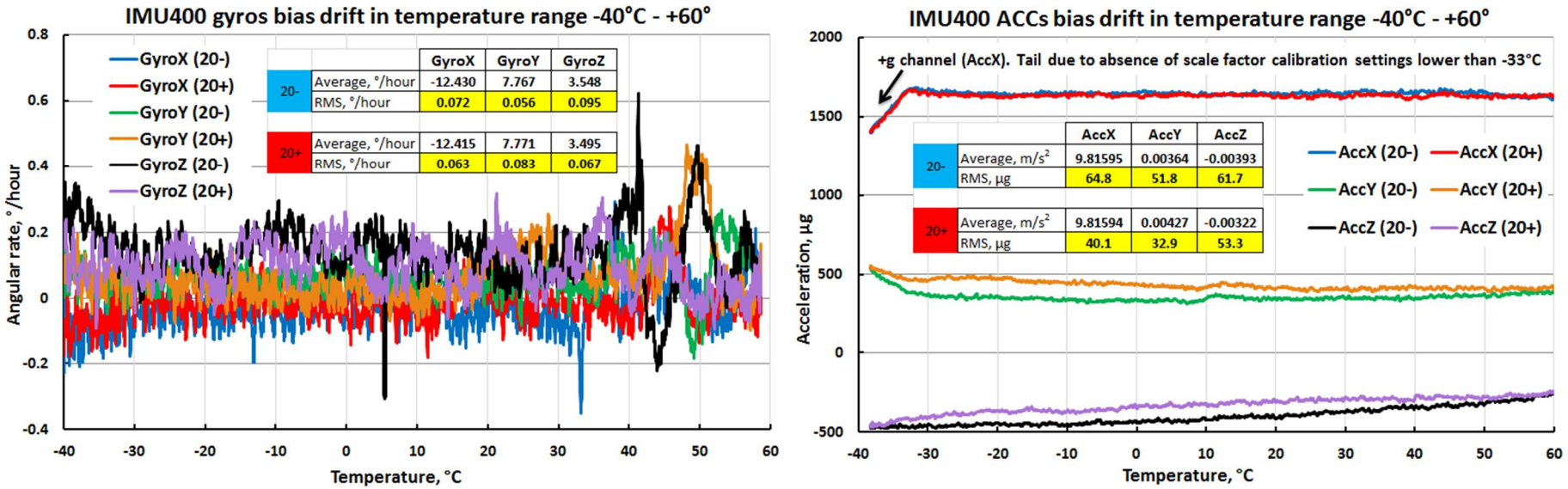
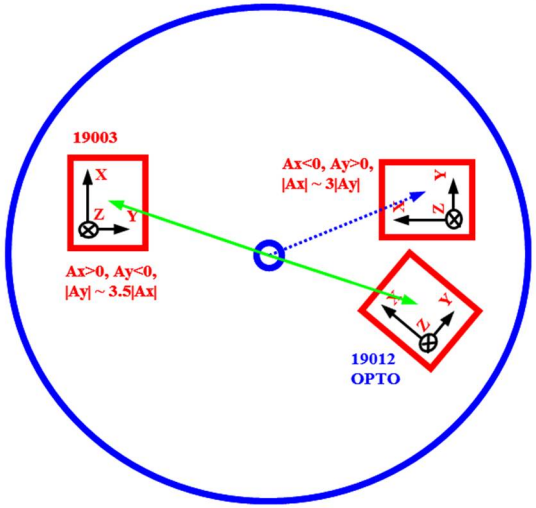


IMU400 FOG and ACC channels Allan variance plot



IMU400 Gyroscopes & Accelerometers bias plots in temperature range

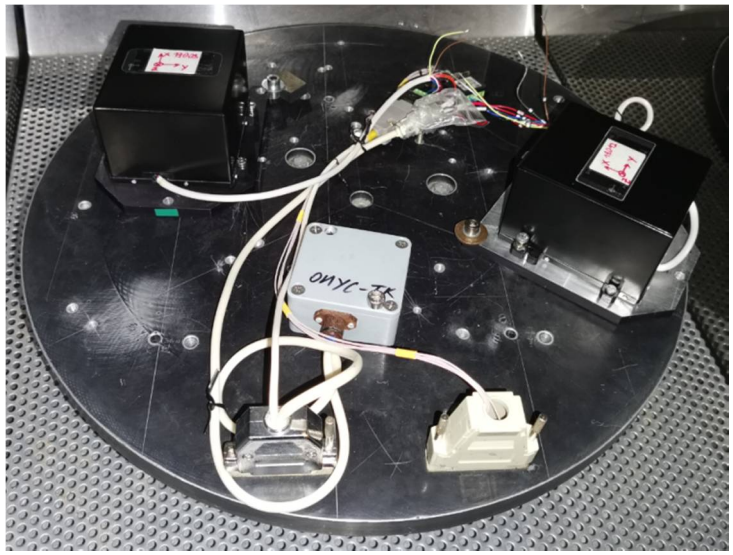
3a. MEMS accelerometers SF non-linearity



Test setup design:

- Precise rate table (self-made at Optolink) with multiple mounting holes 2 IMUs in tests, balanced wrt center. Effective radii ~10-13cm. Rotation rate up to 2000°/s.
- IMU positioning not only with definite (a) axes along centripetal, but with random (b) acceleration distribution over channels – for even estimation of 3-axis MEMS sensors

(a) IMUs with definite (-Z) axes along centripetal acceleration

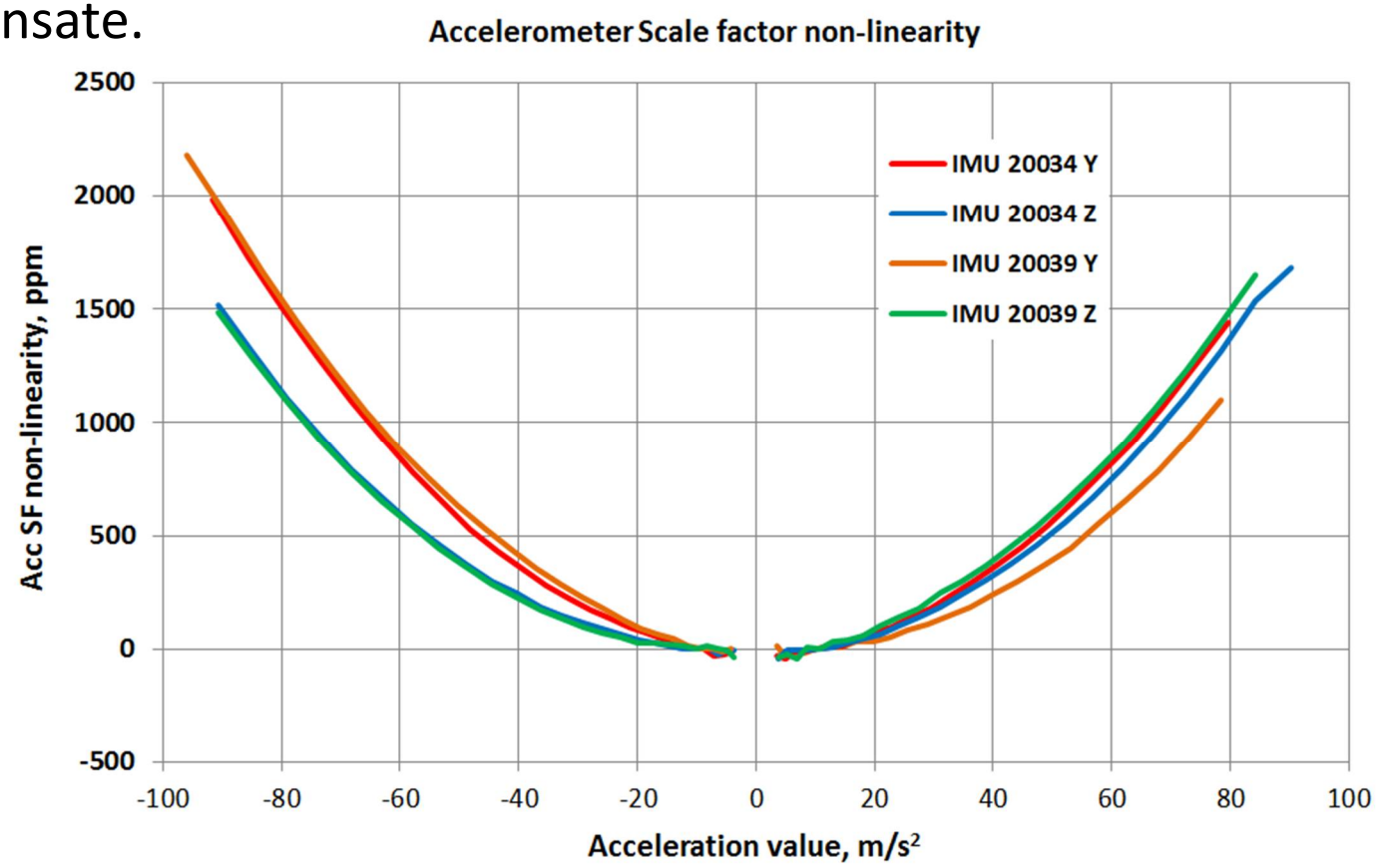


(b) random acceleration distribution over channels

3a. MEMS accelerometers SF non-linearity

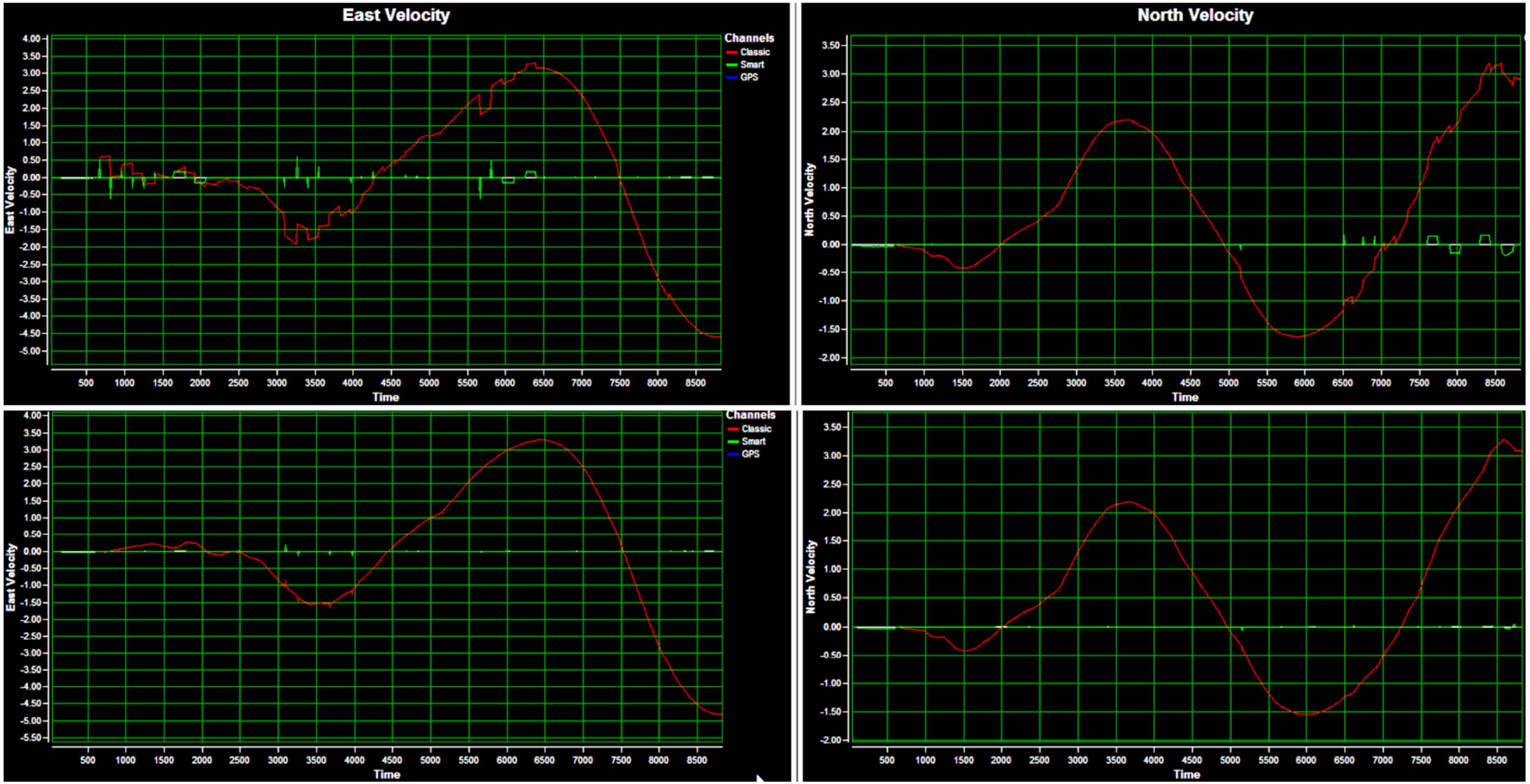
Results - for random IMU positioning (b):

- Accelerometers have predictable non-linearity pattern which can be compensated, if needed. May be asymmetric.
- Errors scale is ~2000ppm non-linearity error at ±10g.
- However, at ±2g <100ppm. Therefore, for the civic/marine range of applications, no need to compensate.



3b. MEMS accelerometers delay

- Initial IMU400 design showed measurement delay between Gyro/Acc triads as whole (upper image, 2019-year IMU400 calibration launch, inertial velocities).
- In 2020, we improved schematics to get rid of the delay and thus making inertial behavior better (lower image, removing delays in post-processing).



4a. Test results, gyrocompassing

Heading °	1	2	3	4	5	6	Average for	Dispersion for	RMS for Heading, °
0	0.195	0.034	0.380	0.002	0.098	0.279	0.1647	0.0452	**0.212**
90	90.339	90.513	90.541	90.276	90.051	90.398	90.3531	0.1514	**0.389**
180	179.857	179.605	179.770	179.926	179.778	179.731	179.7779	0.0594	**0.244**
270	269.555	269.798	269.531	269.476	269.569	269.804	269.6221	0.1597	**0.400**
0	0.011	-0.192	-0.278	-0.023	0.145	0.115	-0.0226	0.0211	**0.145**

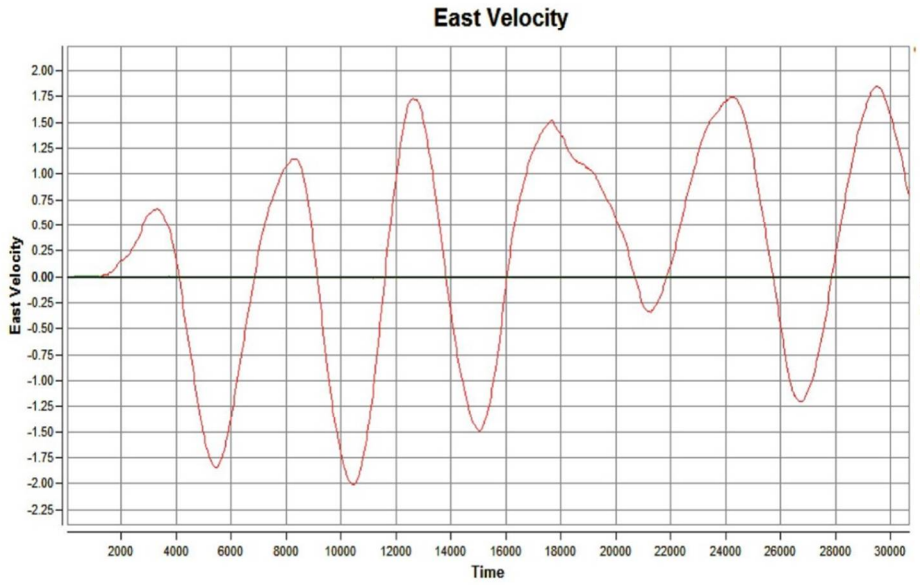
	Bias, °/hour		
	X	Y	Z
test1	0.028	0.054	-0.019
test2	0.036	0.040	0.008

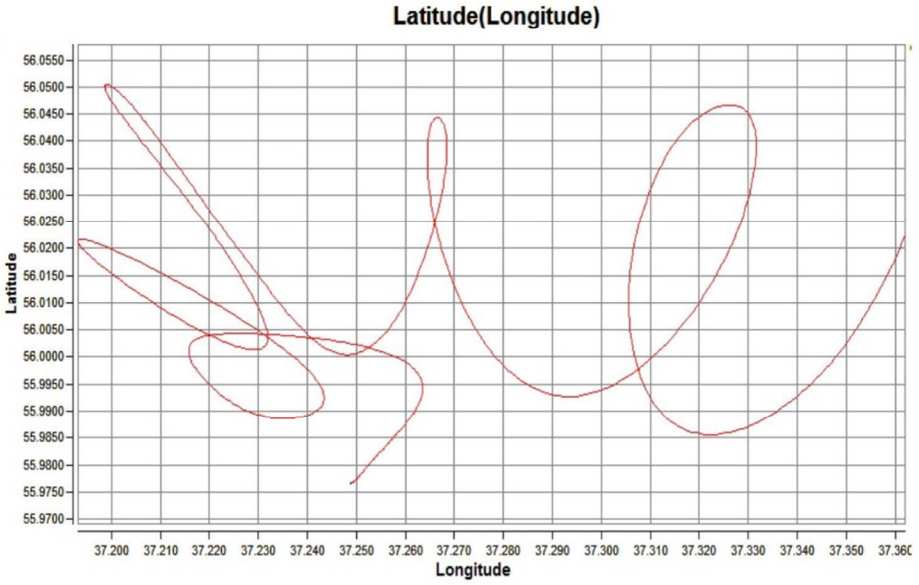
At 56° N Lat.

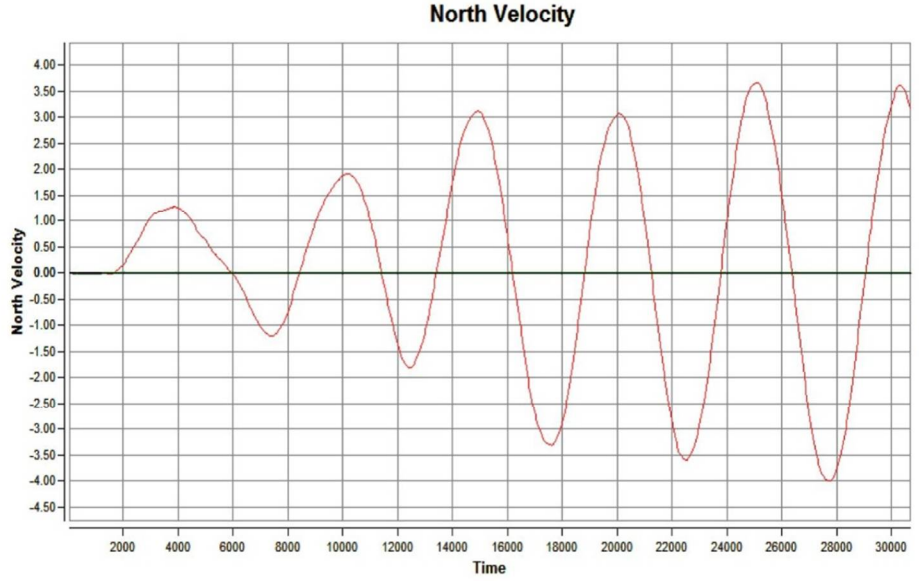
Total disp.	Total RMS
0.0979	**0.313**

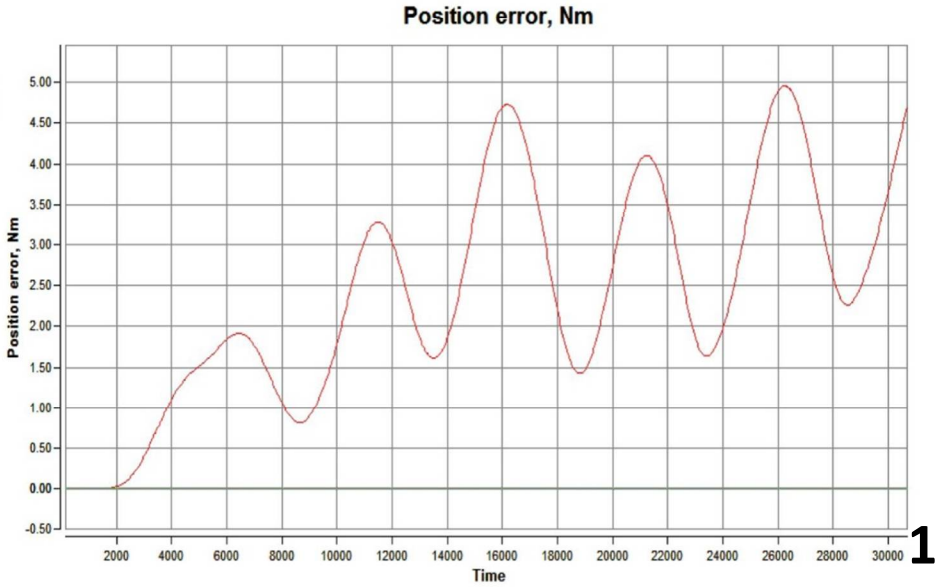
	Cardinal direction					
	0°	90°	180°	270°	0°	Average
RMS (Mean-shifted), °	0.147	0.179	0.110	0.142	0.153	0.146

4a. Test results, static – 5Nm at 8h

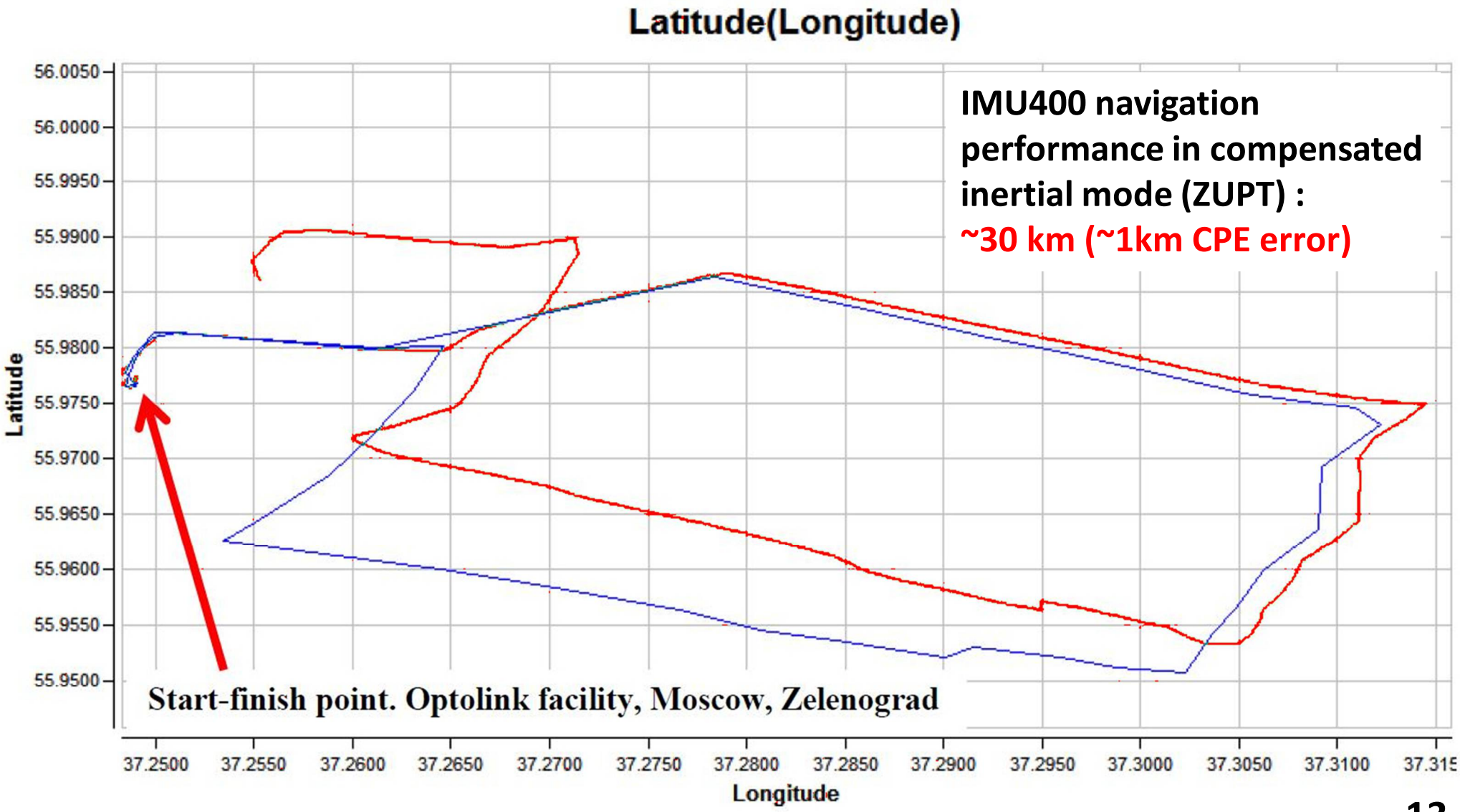




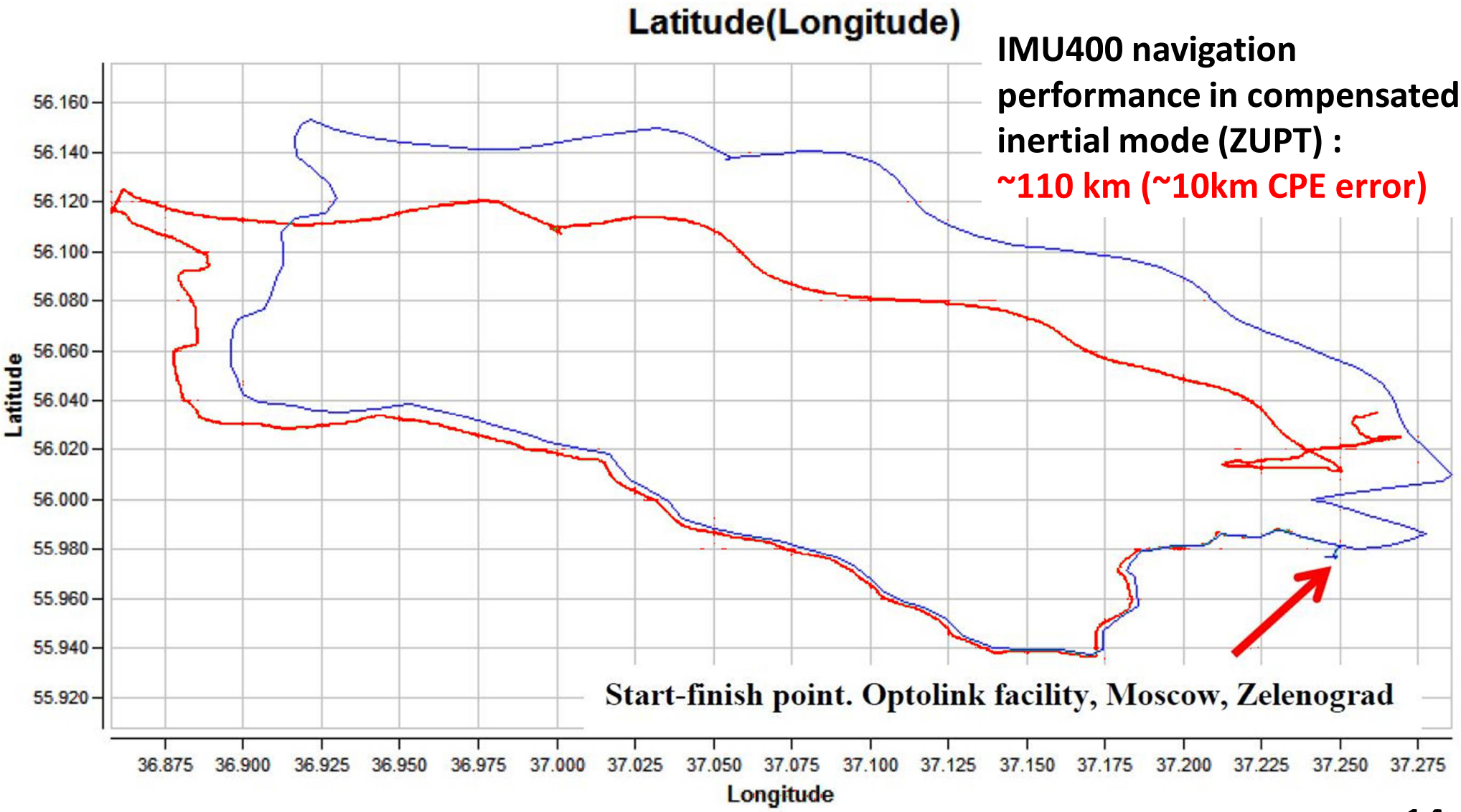




4b. Test results – track navigation 1



4b. Test results – track navigation 2



IMU400 navigation performance in compensated inertial mode (ZUPT) :
~110 km (~10km CPE error)

5. Conclusion

Demonstrated performance allows to assess IMU400 as navigation or near-navigation grade IMU with unique combination of performance / cost / SWaP characteristics.

> 100 units already delivered to customers (2019.06 till now)

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