

, 15, 49005, ; e-mail: oksana.volosheniuk@gmail.com

( ), ( ).

Digital Globe, Planet Labs, Black Sky, Satellogic S.A.,

The aim of this work is to identify the global trends in the use of low-orbit spacecraft constellations, which have a number of substantial advantages in Earth remote sensing (ERS). Much attention is given to the construction of large constellations of single- and different-type spacecraft by foreign companies and operators, such as Digital Globe, Planet Labs, Black Sky, Satellogic S.A. etc., and to the plans of deployment of constellations of this type in the USA, China, Japan, Canada, Europe, and other countries. The characteristics of the various, mainly commercial, low-orbit constellations of optoelectronic Earth observation spacecraft put into orbit over the past five years are considered. It is shown that low-orbit spacecraft constellations can be used to good advantage in the solution of numerous socio-economic problems, such as geodesy and cartography, urban development, transport infrastructure, crop estimate, environmental monitoring, health monitoring, etc., and new problems aimed at prompt continuous monitoring of various objects. The paper presents a comparative analysis of the technical implementations and ways of achievement of the main target spacecraft characteristics, such as information performance, capture range, revisit time, geodetic connection accuracy, imaging immediacy, and the possibility of stereo and video imaging by satellite constellations. It is shown that the construction of large low-orbit constellations is a new trend in the world astronautics, which requires systematic methods for their design and control. The results obtained allows one to make recommendations on the design of low-orbit constellations of home ERS spacecraft, in particular on the development of orbit determination models and algorithms and spacecraft dynamics models.

**Keywords:** Earth remote sensing, low-orbit spacecraft constellation, optoelectronic observation system, spatial resolution, information performance, immediacy.

( )

[1].

( )

( );

© . . . , 2020

. - 2020. - 3.



(2015–2020)

1–

2015

KompoSat-3A		2015	0,55	2,2	13	528	1000
IGS O5- 7		2015–2020	0,4	–	–	500	4100
DMC-3 A,B,C		2015	1	4	23,4	650	447
Jilin-1		2015	0,72	2,88	11,6	650	430
CartoSat-2C		2016	0,65	2,0	11,0	510	727
-		2016	0,7	2,1	38,6	475	6270
SkySats 1–5		2016	0,7	1,56	6,25	500	90–120
WorldView-4		2016	0,31	1,24	13,1	617	2087
SuperView-01, 02		2016	0,5	2	12	500	500
SkySats 6–21		2017–2020	0,5–0,7	1,56	6,25	400–575	100/120
- -		2017	2,1	10	23	510	600
- 3–6		2018	2,1	10,5	23; 40	510	500
BSG 1–4, 7, 8		2018–2020	1	–	–	450	44–65
CSO-1, 2, 3		2018	0,35/0,2	4	23	800/480	3565
GF 1-02–04, 5–7, 11, 12		2018, 2019	2	8	90	500–700	805
Jilin-1 GF-02A, 02B		2019	0,76	3,1	40	535	230
Jilin-1 GF-03A		2019	1,06	4,24	18,5	579	42
Jilin-1 Guanpu-01,02		2019	–	5	110	528	202
GF 9-02, 03		2020	0,8	3,2	48	500	–
CAS-500-1/2		2020	0,5	–	12	600	500
Jilin-1 GF-01		2020	1	4	136	485	1250

.1

**Planet Labs.**

Planet Labs ( ) [4]. 6

351

Planet Labs

3

24- ; 5

RapidEye,

: 21 SkySats,

	BlackBridge; 179	PlanetScope (Flock).	
			100
		250	<sup>2</sup> ,
1 200	-	3-	(SkySats 16-18,
. 1)	2020 . 3-	(SkySats 19-21)	-
		7	
	[4].		53° 12
		0,5	-
			-
		Planet Labs.	
	<b>RapidEye</b>	6,5	-
		[5].	-
	RapidEye		,
		31.03.2020 .	11
	RapidEye		-
Flock	[4].		-
	<b>Flock</b>	-	2,7 5 .
	( )	( 3/4)	-
			3,7 .
			150 . <sup>2</sup> .
			90
			-
3	11/12		Flock-
		29	475
	3,73 ,	(24,6×16,4)	403 <sup>2</sup> .
	-	20 [6].	
		<b>SkySats</b>	
	~40 .	(11×6)	66 <sup>2</sup> .
	768 ,	450 / .	-
		40	
	90	HD (1920×1080	)
	30 .		-
	HD (2560×2160	- 5,5 ) .	
	640 .	(2,0×1,1)	
	8 .		-
		Flock SkySats,	
			-
			-
			-
			-

[7]. (20–50) (40–80) ( 100 ). (100 ), Planet Labs Euroconsult [8] (Planet Labs, Black Sky, Maxar, Satellogic S.A.) 1400 2025 . 2 ( 6- ), 2025 . 2 – 2025 .

Flock	Planet Labs		3,7	4,5
Pelican	Planet Labs		0,29	–
BSG	BlackSky		0,9–1,1	44–65
NuSat	Satellogic S.A.		1,0	37,5
Landmapper	Astrodigital		2,5	20
Zhuhai-1	Zhuhai Orbita Aerospace		1,98	55
SkySats	Planet Labs		0,7–0,9	83/120
WorldView-Legion	Digital Globe		0,35–0,5	500–700
Grus	Axel Space		2,5	80
OptiSar Optical	Urthe Cast		0,25–0,50	340–670
UrtheDaily	UrtheCast		5	340
Super View	SuperView		0,5	500

**Digital Globe.** Digital Glob [9], Maxar Technologies ( ), (WorldView-1, 2, 3, 4 GeoEye-1) 700 . 2. 4,5 , WorldView-3, 4, 0,25 Planet Labs) Digital Globe WorldView-Legion WorldView-Legion 2021 .

15 [10]. WorldView Legion

Digital Globe.  
0,29 , 5 ; <sup>2</sup> ( 700 . <sup>2</sup> -  
10 ) [10].  
Taqnia Space The King Abdulaziz  
City for Science and Technology (KACST) -  
6- WorldView-Scout  
1 (0,8 3,2 ), -  
2021 . [11].  
40 , -  
0,8 , -  
0,3 WorldView-3, 4. -  
Digital Globe , ,  
.  
**BlackSky.**  
BlackSky [12], 2013 .  
BlackSky Global (BSG) 60-  
(0,75–1) (44–65) , -  
.  
90 % , 55° -  
( ) . -  
BlackSky 8 BSG , -  
BSG 7, 8 07.08.2020 ., -  
2020 . 2021 . BSG 16 . -  
450 . -  
1 / , -  
(10–15) . [12].  
BSG -  
SV-24™ ( ) 0,24 . -  
Harris Corporation « -  
» - ( -  
SpaceView™) 0,24 0,7 -  
[13]. , 1 -  
(0,5–0,7) , BSG  
0,24 .  
BlackSky ( , -  
) , ,  
.  
Planet  
Labs, Digital Globe, BlackSky , -  
, ,  
, .

(Tianhui, Ziyuan-3),  
 (Yaogan, Gaofen, Jilin-1), (Lingqiao) [14, 15]  
 2015  
 3 DMC-3  
 Surrey  
 Technology Ltd (SSTL,  
 China Great Wall Industry Corporation (CGWIC)  
 2019 CGWIC  
 Satellogic S.A. ( )  
 – NuSat.  
 8 NuSat, 90 [16].  
 – SuperView-1.  
 SuperView Constellation.  
 SuperView-1,  
 ( ), [17].  
 SuperView-1, Gaofen, Jilin-1  
 . 1.  
 2016 .  
 ( 500 )  
 SuperView-01, 02 ( Gaojing-1-01, 02)  
 0,5 [18]. 2018 . 2 (Gaojing-1-03, 04),  
 2022 . 16 .  
 ± 30°.  
 (60×70) [19].  
 Gaofen 1 (GF 1) –  
 China High-Definition System

Observation System (CHEOS) -

GF 1 -

GF 1 -

GF 1-02, 03, 04 -

2013 -

- GF 1, -

[20]. -

2 8 -

GF 1 [15]. -

GF 7 -

1 . 3.11.2019 . 1:10000. 5 ,

3D - 1,5 .

GF 9 -

31.05.2020 . 17.06.2020 . - GF 9-02, 03,

0,8 3,2 -

48 «Pushbroom» ( -

2- -

2015 . 2 Lingqiao Video-A, -

4 (3840×2160 ), -

(4,3×2,4) <sup>2</sup>, -

Lingqiao SkySats. -

2018 . -

Lingqiao-08, 09, Jilin-1. -

Jilin-1 -

Jilin-1 7.10.2015 . [14]. 650 -

0,72 2,88 . 11,6 , -

- 3,3 . : , -

Jilin-1 Gaofen 03A, 5.06.19 . -

18,5 . -

«pushbroom», «multi-target pushbroom», «space target», -



$\pm 45^\circ$ . 5 , ,  
 100 [14].  
 Jilin-1 Gaofen 02 A, B [14], 13.11.2019 .  
 7.12.2019 . - , Chang  
 Guang Satellite Technology Co. Ltd (CGSTL) [14].  
 HD . -  
 .  
 0,76 ,  
 3,1 . 40 ;  
 300 , - 1,8 / .  
 Jilin-1 Guanpu 01, 02 - .  
 .  
 60- 2020 .  
 138 2030 . : -  
 , , , ,  
 - 5 ,  
 - 100 , -  
 - 150 , - 110 ,  
 - 26. - 528 , - 97,54°,  
 2-3 , - 1 .  
 : 600 / , 300 / , 150 / , 900 / . -  
 , - 50 , -  $\pm 45^\circ$ .  
 Jilin-1 GF-01, 15.01.2020 . 485 , -  
 Jilin-1 [21]. Jilin-1 GF-01  
 0,75  
 3 , 136 . -  
 1000 <sup>2</sup> . -  
 1 . <sup>2</sup> . Jilin-1 FG-01  
 40 , -  
 22,4 / . -  
 1,8 / , ,  
 .  
 0,29  
 (250-550) 40°-60° 96°-99° . , Jilin-1 GF-  
 01 - -  
 , -  
 15- Jilin-1, .  
 , .  
 .  
 (CAST) .  
 , -  
 .

«Space and Major Disaster» ( ).

-  
 ;  
 ;  
 -  
 - IGS (Information Gathering  
 Satellites) Alos (Advanced Land Observation Satellite)  
 IGS 2003 . -  
 4 1,2 . 4- . 4  
 (468–526) 97°–98°. IGS Optical 7,  
 09.02.2020 – IGS -  
 ( 0,4 ), -  
 4,1 .  
 Alos -  
 (631–640) 98°. Alos -  
 2,5 10 -  
 L- 1 . -  
 Asnaro, 2014 .  
 Asnaro NEC Corp. USEF (Institute for  
 Unmanned Space Experiment Free Flyer) 2008 .  
 , 100 500 , -  
 , , -  
 [22]. :  
 0,5 , – 2 , -  
 – 10 , – 800 / . -  
 Asnaro-3. -  
 CE-SAT-1B. , 23.06.2017 . -  
 CE-SAT 1 (Canon Electric Satellite 1 ) -  
 (0,5×0,5×0,7) , 50 . -  
 1 600 , (6×4) . -  
 . 05.07.2020 .  
 CE-SAT-1B.  
 Canon Electronics Inc. -  
 CE-SAT 1 ,  
 0,9 600 , 67 .



3

Pleiades 2020-2021 1 2 1 4 -

CSO-1/2/3 (Composante Spatiale Optique), 19.12.2018 ..

of Armaments) CNES. 3565 DGA (Directorate General Helios. CSO-1 ( 800 ) 0,35 , 23 , CSO-2 480 , CSO 30 % 0,2 . 40 % [24].

2006 . - 1.

,8 -3 « - » -0,8 , -12/24 -30 ;

-5 « - » -2,5 -12 ; -2 « - »

1000 -2 (50-70) , 2-3- ;

« - » 30 . ( 500 1000 ) « - SSSL-300S1 (0,9x0,9x0,75) .

- » 500 5 , 2,1 23 . 4- -10,5 .

, « - 1». « - » , 3- « - » : RPC-

, ; ( ) . « - »

80 000 . 2 , 2100 ( 300 c).

« - » ,



[16]. NuSat (Aleph) 8- Satellogic S.A. 2016 .  
 2- Satellogic S.A. . NuSat 7, 8  
 2020 ., NuSat 6 – 2020 .  
 (0,51×0,57×0,82) , 37,5 -  
 , 1 ,  
 30 (150 470 ) , -  
 90 .  
 6 , 25 -  
 6 , 1,2 , 100 -  
 15 , 300 – 5 NuSat 90 -  
 ,  
 300 , -  
 , Satellogic  
 – CGWIC. -  
 3 -

3 –

		,	,	,	,	,
SkySats	2013–2020	80–120	1920×1080	1,1	2,0×1,1	90
Lingqiao Video-A, B	2015	95	3840×2160	1,13	4,6×3,4	120
Jilin-1GF 03A	2019	165	HD	0,92	11×4,5	300
Carbonite-1	2015	90	HD	1,5	–	15
Carbonite-2	2018	100	UHD, 4096×2160	1,2	5,9×5,9	120
Jilin-1 GF 02A, 02B	2019	208	HD	0,76	19×4,5	300
NuSat	2016–2020	37,5	HD	1,0	–	–

( Planet Labs).  
 ( NuSat, SkySats, BSG, Jilin-1 Guanpu . ).  
 ( ,  
 ), ' ,  
 ( , Lingqiao Video A, B, Jilin-1 GF).

