Introduction to BDS-3

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1. Introduction

■ **Names of China Navigation Satellite System**

Names of China Navigation Satellite System

Compass

Before 2014

BeiDou

The big dipper
Charles's Wain

After 2014

1. Introduction

■ Why Compass?

- Battle between Huangdi（黄帝）vs Chiyou（蚩尤), 2697 before Christ（compass was invented）
- Huangdi's army lost their direction, a Fairy clued to Huangdi that Compass could direct the South, thus compass which uses the magnetism property directing the earth poles (poles not included) was invented
- Compass was named as the China's navigation satellite system

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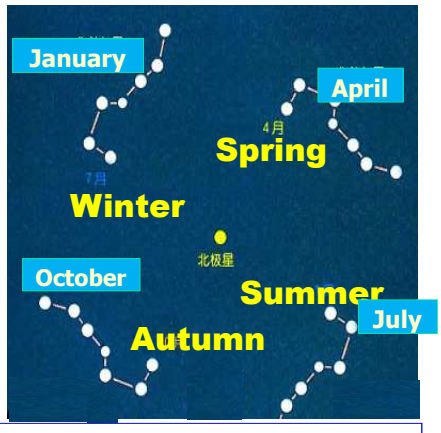
1. Introduction

■ Orientation by the Big Dipper (Chinese worship the Big Dipper)

- Many beautiful legend left to Chinese by Charles's Wain (or the Big Dipper, Triones---BeiDou)
- The Big Dipper not only tells us direction but also the seasons. 《易鸟冠子》: dipper handle directs east—spring; south—summer; west—autumn; north—winter
- What can China BeiDou do?—PVT+Orientation



- BeiDou satellite navigation system can do much more!

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1. Introduction

Compass in ancient China

- Qin & Han Dynasty: Traffic among China, Korea & Japan on the sea
- Sui & Tang Dynasty: Trade btw China & Arabian countries
- Song dynasty: Chinese ships on Pacific & Indian Ocean
- Early Ming dynasty : Navigator, He ZHENG voyaged down the western seas seven times

◆ Compass and BeiDou orientation were very important tool for navigation

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2. BDS-1 and BDS-2

◆1st step: BeiDou demonstration system

- Provide positioning, timing and short message communication from 2003
- Sevice area: 70°-140°L; 5°-55°B
- Positioning precision: <20m, timing precision<100ns
- Short message communication: 120 Chinese characters/time

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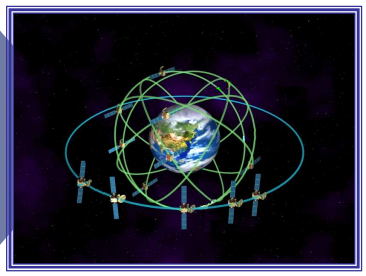
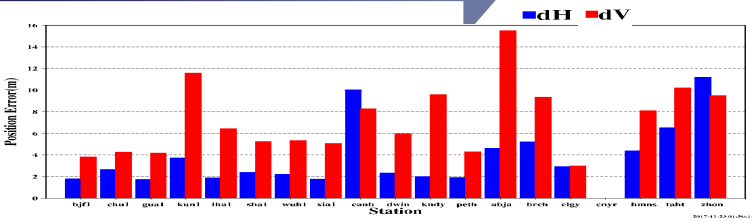
2. BDS-1 and BDS-2

◆ 2nd step: Regional navigation system

14 satellites: 5 GEO, 5 IGSO, 4 MEO

Service area: -55°~55°B, 55°~180°L





Most area: 5m

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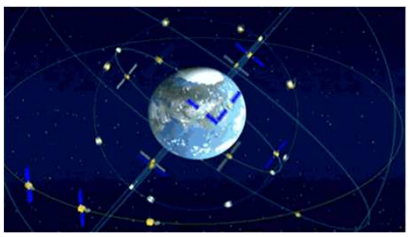
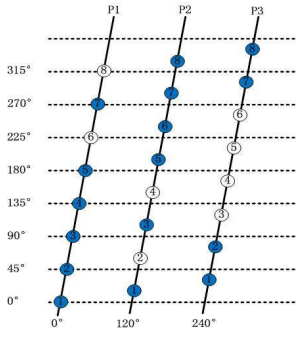
3. BDS-3 new design and service

3.1 Basic design of BDS-3

- Started from Sep., 2016
- Constellation: 30 satellites with 3GEO, 3IGSO and 24MEO satellites
- Whole system construction will be finished in 2020
- 19 satellites are on orbit (now)





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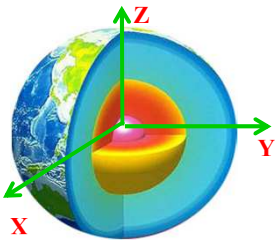
3. BDS-3 new design and service

3.1 Basic design of BDS-3---coordinate reference

- Coordinate reference of BDS-3 is consistent with ITRF, called BDSC
- a=6378137m, the same as that of GPS, different from GLONASS or Galileo
- Flattening f=1/298.257222101, different from that of other GNSS, GM is also different from other GNSS



- BDSC of BDS-3 updates yearly, by using multi-GNSS receiver to tracking BDS and other GNSS
- Employ the integrated adjustment of the tracking data and measurements of ITRF stations

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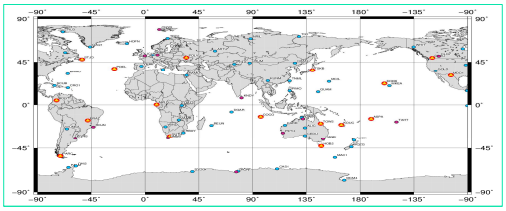
3. BDS-3 new design and service

3.1 Basic design of BDS-3---coordinate reference

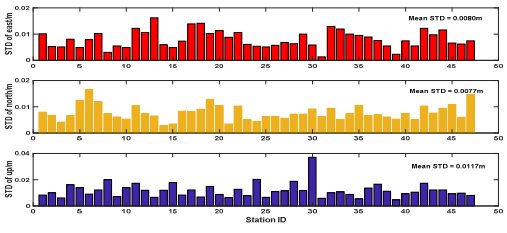
■Test results-Coordinate repeatability



52 IGS stations (3 domestic stations) with BDS/GPS receivers were used to calibrate the BDSC (2018.4-2018.5)

Repeatability in N, E & U are 0.77cm, 0.80cm & 1.17cm respectively

Translations btw BDSC and ITRF are -2mm, 4mm & -8mm respectively



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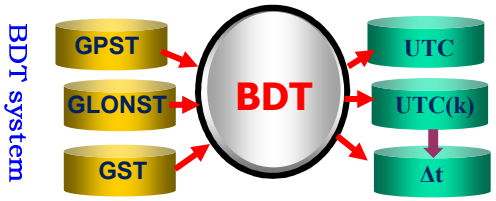
3. BDS-3 new design and service

3.1 Basic design of BDS-3---System time

- BeiDou time (BDT) is aligned to UTC indirectly, first aligned to NTSC (national time service center), then UTC
- GNSST my be choice in the future
- A unified China time system is in construction, by connecting all time keeping centers in China



- ✓ BDT is in improving by adding new clocks
- ✓ Stability accuracy are improving

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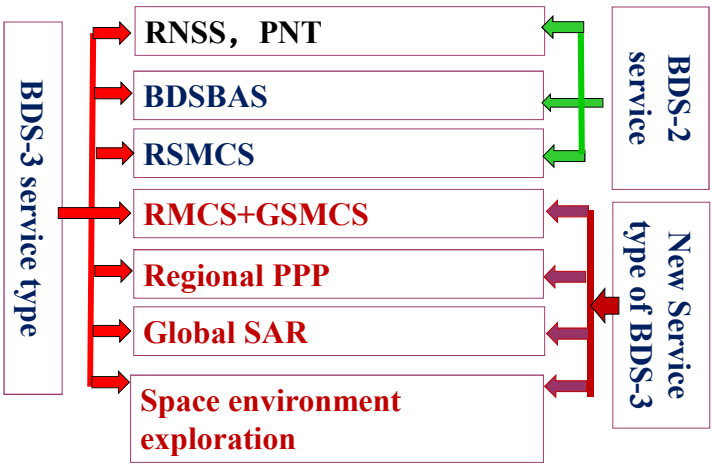
3. BDS-3 new design and service

3.1 Basic design of BDS-3---Service and design target



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3. BDS-3 new design and service

3.2 Signals of BDS-3

Service type		Signal frequency	Satellite
RNSS	Open	B1I, B3I, B1C, B2a, B2b	3GEO+3IGSO +24MEO
	Authorized	B1A, B3Q, B3A	
SBAS	Open	B1C, B2a	3GEO
	Authorized	B1A	
Regional message communication services (RMCS)	Authorized	L(uplink), S(downlink)	3GEO
Global short message communication services (GSMCS)		L (uplink), B2b (downlink)	14MEO
International SAR service		Uplink: 406MHz downlink: 1544-1545MHz	6MEO
Transmission of precise positioning information		B2b	3GEO

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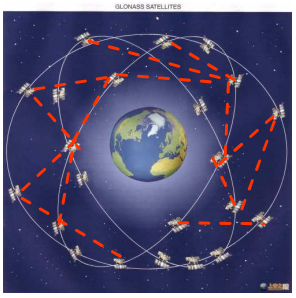
3. BDS-3 new design and service

3.3 Inter-satellite links

- Inter-satellite links (ISL) with Ka phased array and laser are added in BDS-3 satellites
  - ✓ to solidify relative position of whole constellation and improve the orbit determination accuracy
  - ✓ to help time synchronization
  - ✓ to strengthen Search & Rescue
  - ✓ to improve efficiency and reliability of short message communication
  - ✓ to carry out autonomous orbit determination (AOD)



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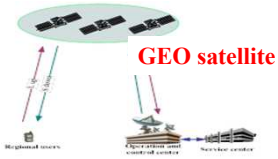
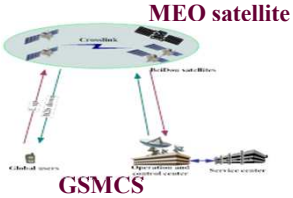
3. BDS-3 new design and service

3.4 Message communication service (MCS) of BDS-3

- MCS of BDS-3 is divided into regional message communication service (RMCS) (via GEO) and global short message communication service (GSMCS) (MEO)
- RMCS: 1000 Chinese characters per time for users in China & surrounding area; communication volume is extended by 10 times, while transmit power is only 1/10 (compared with BDS-2); supports mobile phones
- GSMCS: provided by 14 MEO & ISL with 40 Chinese characters per time (location report, emergency SAR)



RSMCS



GSMCS

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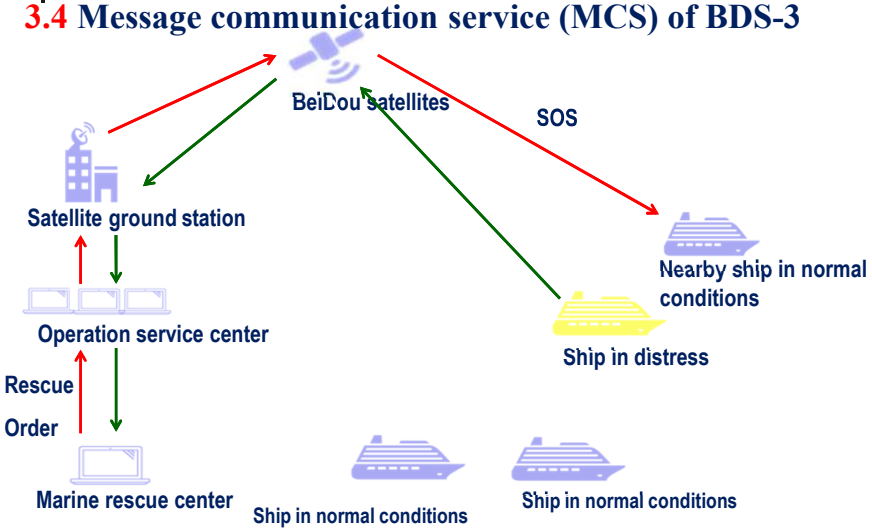
3. BDS-3 new design and service

3.4 Message communication service (MCS) of BDS-3



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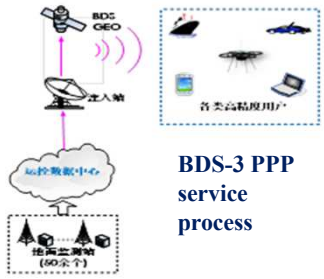
3. BDS-3 new design and service

3.5 PPP service of BDS-3

- Precision point positioning (PPP) service will be provided by 3 GEO via B2b (China & surrounding areas)
- Orbit, clock bias corrections, differential code biases & other parameters will be broadcasted (dual-frequency positioning possible, ionospheric free)



BDS-3 PPP service process

- Regional PPP users can get decimeter-level kinematic positioning and centimeter-level static positioning results after 20-30 minutes for convergence

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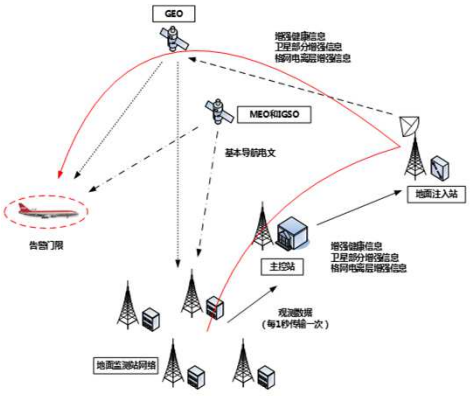
3. BDS-3 new design and service

3.6 Satellite Based Augmentation （BDSBAS）

- BDSBAS follows ICAO standards and SARPS
- Service area: China and surrounding area
- Service satellite: 3 GEO (80° E, 110.5° E & 140° E)
- Service frequency: SBAS-B1C, SBAS-B2a
- Augment object: Four constellations (BDS at first)



- Service mode: SFDC and DFMC, meet the requirements of precision approach phase CAT-I of international civilian aviation

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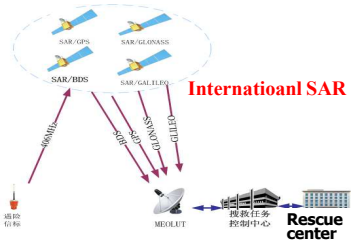
3. BDS-3 new design and service

3.7 Global SAR of BDS-3

- BDS SAR follows the related standards of IMO, and will provide free SAR service with other COSPAS SAR satellite constellations for global voyage, aviation and land users
- 6 MEO satellites (on 3 orbit planes) mounted with SAR device will provide reliable distress alarm service to global users



Main functions of the research and rescue are nearly the same as international SAR service

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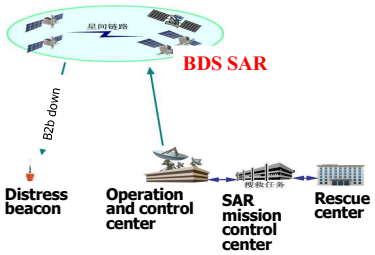
3. BDS-3 new design and service

3.7 Global SAR of BDS-3

Two differences of BDS SAR from the standard SAR service

- ✓ Return link
- ✓ Inter-satellite link



- Return links are designed in BDS SAR for improving the SAR efficiency and success rate, by which the users do not need to repeat call for help
- Inter-satellite links helps to improve communication efficiency between SAR center and rescuee
- Laser links will help much more

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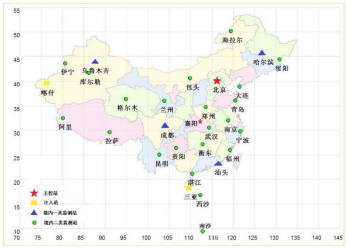
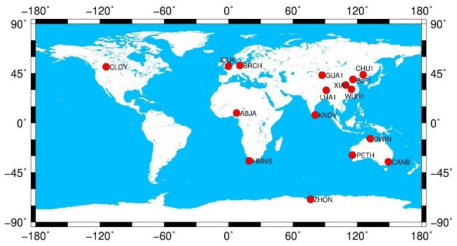
4. Preliminary performance of BDS-3

■ Domestic tracking stations and iGMAS

- Evaluation by OCS of BDS with domestic tracking stations
- Evaluation by international GNSS Monitoring System (iGMAS)
- Evaluation content
  - ✓ Satellite clock
  - ✓ Satellite orbit
  - ✓ SISRE
  - ✓ …





4. Preliminary performance of BDS-3

■ Orbit accuracy of the simplest BDS-3 constellation (8 sat)

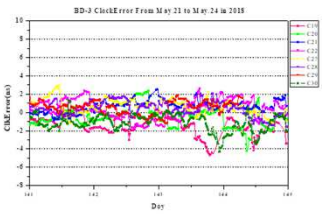
Statistics of satellite orbit (m)

Satellite	R	T	N	POS
C19	0.103	0.563	0.584	0.823
C20	0.105	0.53	0.43	0.691
C21	0.163	0.709	0.667	0.984
C22	0.184	0.648	0.729	0.997
C27	0.207	0.579	0.676	0.913
C28	0.217	0.586	0.567	0.842
C29	0.252	0.909	1.502	1.767
C30	0.312	0.971	1.195	1.574

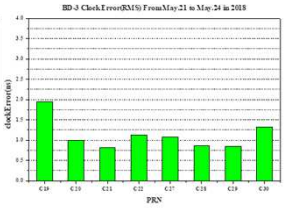
Radial: 0.1-0.3m; Tangential: 0.5-1.0m; Normal: 0.4-1.5m

4. Preliminary performance of BDS-3

- **Satellite clock error of the simplest BDS-3 constellation**
  - Satellite clock errors are averagely 1-2ns
  - Apparent disturbances are observed on certain satellites in certain period of time. Hydrogen clocks are very stable



Clock error sequence



Satellite clock error (ns)

Clock accuracy

Satellite	RMS	Satellite	RMS
C19	1.951	C27	1.078
C20	0.995	C28	0.861
C21	0.812	C29	0.84
C22	1.124	C30	1.319

  - Next generation satellite rubidium clocks or cesium clocks will be more accurate and stable

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4. Preliminary performance of BDS-3

- **Main results**
  - 3D RMS of overlapping orbit differences
    - ✓ RS: 1m
    - ✓ GS: 0.5m
    - ✓ RS + ISL: 0.5m
    - ✓ GS + ISL: 0.3m
  - 3D orbit accuracy of BDS-3 satellites after 24h prediction
    - ✓ RS: 2.03m
    - ✓ RS + ISL: 0.73m
    - ✓ GS: 0.93m
    - ✓ GS + ISL: R: 0.09m; T: 0.53m; N: 0.11m
    - ✓ GS+ISL: 3D: 0.56m

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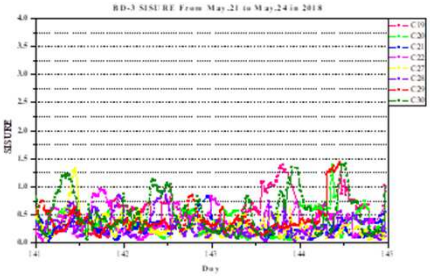
4. Preliminary performance of BDS-3

■ **SISRE of the simplest BDS-3 constellation** (domestic)

User ranging error sequence



User ranging error (m)

Satellite	RMS	Satellite	RMS
C19	0.645	C27	0.375
C20	0.342	C28	0.383
C21	0.301	C29	0.373
C22	0.420	C30	0.652

- SISRE are averagely 0.4-0.5m at domestic tracking stations
- Note: SISRE of GPS and BDS-3 are seemingly equivalent, but the former is the global average accuracy, while BDS-3 mainly monitored in China

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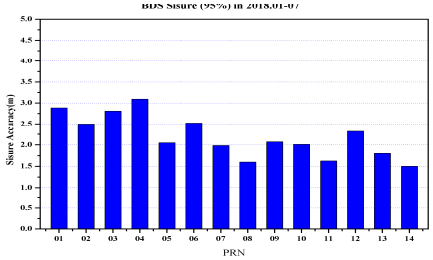
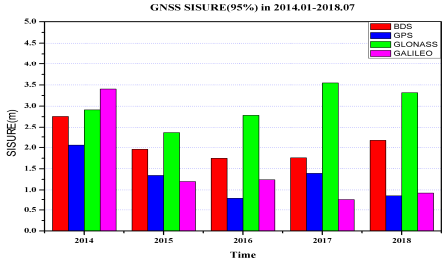
4. Preliminary performance of BDS-3

■ **URE of the simplest BDS-3 constellation** (iGMAS)

BDS 2018/1-7 (95%)



Compare to other GNSS



- iGMAS monitoring results:
- Radial orbit accuracy: 0.4m;
- Satellite clock accuracy: 0.7m (2.2ns);
- SISRE: about 2m

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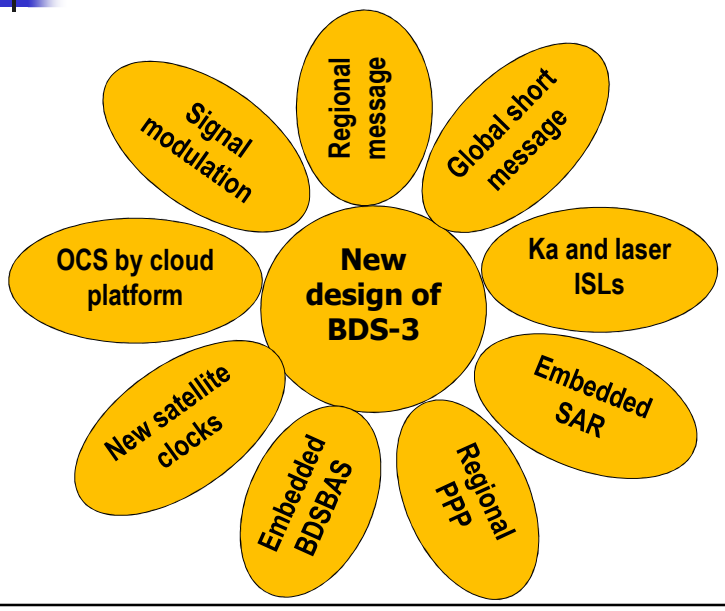
5. Conclusions



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5. Conclusions

- New designs of BDS-3 will improve service functions
- The signal accuracy of BDS is comparable to other GNSS signals
- Orbit accuracy determined by ISL+regional tracking stations achieves about 0.5m, nearly achieves the results of global tracking stations
- Regional and global message communications will help the management of sea fishing and transportation as well as search and rescue
- Reginal PPP and BDSBAS are embedded in BDS-3
- Whole constellation will be established in 2020 with 30 satellites, global PNT service will be provided
- BDS-3 will be available and helpful for ITRF

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Thanks !