OREKIT DEVELOPMENT STATUS

Orekit Team (Maxime Journot)
AGENDA

1. History
2. Major features
3. Project Organization
4. Trends – v10.0 & beyond
OREKIT HISTORY

Inception | 2002
Orekit intended as a basis for ground segments bids

Failure of the commercial approach | 2008
Exceeds technical expectations, why not propose it by itself?

Version technically complete | 2006

OPEN-SOURCE!
Permissive license. Very good reception by space community

Bazaar development model | Since 2011
Collaborative tools
External committers

Project teams decide when to release

Cathedral development model | 2008 - 2011

PMC representatives from agencies, academics, private companies

Open governance | 2012
OREKIT RECENT RELEASES

- Java 8 Hipparchus
- 7.0
- 7.1
- 7.2
- 8.0
- 8.0.1
- 9.0
- 9.0.1
- 9.1
- 9.2
- 9.3
- 9.3.1
- 10.0
- GPS week rollover fix

Timeline:
- 2015
- 2016
- 2017
- 2018
- 2019
MAJOR FEATURES
MAJOR FEATURES BY VERSION (1/2)

• 6.x series
  • DSST propagator → mean elements propagation
  • Jacobians computation
  • Solid tides & Ocean tides force models
  • New IERS non-rotating origin paradigm for frames
  • Support for IERS 1996, 2003 & 2010

• 7.x series
  • DSST propagator → short periodic elements propagation
  • Second order derivatives for many model
  • General relativity force model
  • 3 different types of solar radiation pressure
MAJOR FEATURES BY VERSION (2/2)

• 8.x series
  • Switch to Java 8 & Hipparchus
  • Batch least-square orbit determination

• 9.x series
  • Extended Kalman filter orbit determination
  • Multi satellites orbit determination
  • Covariance matrix retrieval in orbit determination
  • Parallel, multi-satellite, multi-threaded orbit propagation
  • Taylor algebra → Field propagators
  • GNSS / very high precision → Goal: Precise Orbit Determination
  • Support for any ITRF version (including latest: 2014)
  • JB2008 and NRL-MSISE 2000 atmospheric models
  • Exceptions’ enhancement (Airbus contribution!)
  • New tropospheric and Global Pression Temperature models
MAJOR FEATURES – ORBIT DETERMINATION (1/2)

- **Orbit Determination Methods in Orekit**
  - Batch least-square (8.0)
  - Extended Kalman filter (9.2)

- **Measurements**
  - Range, range-rate, az/el, PVT (8.0)
  - Turn-around range, $\alpha/\delta$, inter-satellite range, phase, position only (9.x)
  - Measurements’ generation package (9.3)

- **Parameters**
  - Orbits (even partial elements), drag, SRP, station biases & positions (8.0)
  - EOP, parametric accelerations, tropospheric delay, ground points displacements, clock offsets of receivers and emitters (9.x)

- **Features**
  - Multi-satellite orbit determination (9.x)
  - Fast handling of ten of thousands of measurements
  - Tropospheric, ionospheric, weather corrections
  - Modularity: user defined measurements, filters, modifiers etc. are easy to add
**Publication:** Maisonobe et al (SpaceOps, 2018), *Multi-satellites Precise Orbit Determination, an adaptable open-source implementation*

**Examples:**

- **Tutorial:** src/tutorials/…/estimation/OrbitDetermination.java
  - Telespazio contribution!
  - **W3B** satellite on a GEO transfer orbit with a propulsive system leak
  - 182 range & 339 az/el measurements from 5 ground-stations
  - Estimation of: orbit, drag, SRP coefficients, all stations range and az/el biases, thrusters’ leak as a parametric acceleration

- **Tests:** src/test/…/estimation/leastsquares/OrbitDeterminationTest.java
  src/test/…/estimation/sequential/KalmanOrbitDeterminationTest.java
  - **LAGEOS2:** Ball-like geodesy satellite on a ~6000km circular orbit
    - 258 laser-ranging measurements from 4 ground stations
    - Estimation of: orbit, SRP, some stations’ position and biases
  - **GNSS:** Earth pointing yaw-steered GNSS satellite
    - 4009 range measurements (CODE-RINEX) from 5 ground stations
    - Estimation of: orbit, SRP, tropospheric zenithal delay
• **Field Propagation**
  - From *Hipparchus* math library
  - Field T is an **enhanced double**
  - Supports all:
    - Double operations (+, -, *, /)
    - Math functions (sin, …, atanh)
    - IEEE functions (scalb,…, copysign)

• **Predefined fields in Hipparchus**
  - **DerivativeStructure**: automatic differentiation
  - **Decimal64**: used for validation in Orekit
  - SparseGradient = DerivativeStructure for Multi-variables + order 1 derivatives
  - Others: Dfp, FieldDerivativeStructure, Tuple, FieldTuple
  - User defined fields can be designed

```java
double f(double x, double y) {
    if (x > 0) {
        return x + g(y);
    } else {
        return x - g(y);
    }
}
```

```java
T f(T x, T y) {
    if (x.getReal() > 0) {
        return x.add(g(y));
    } else {
        return x.subtract(g(y));
    }
}
```
• **Taylor Algebra**
  
  • Using **DerivativeStructure class**
  
  • **Propagate derivatives of any parameters to any order**!
    Typically: 6 orbital parameters to derivative order 3
  
  • **Uncertainties propagation**
  
  • Very fast **Monte-Carlo analysis**
  
  • Others:
    • Accurate state transition matrix & easy Jacobian computation
    • Measurements’ derivatives, GNSS propagators’ derivatives
    • … the potential is huge !!

• **Examples:**
  
  • **Tutorial**: src/tutorials/…/propagation/FieldPropagation.java
    3rd order derivatives of a, i and Ω for a LEO circular orbit
  
  • **Tests**: src/test/…/propagation/numerical/FieldNumericalPropagatorTest.java
    And many other “Field” test classes…
• **Publication:** Antolino A., Maisonobe L. (Stardust Conference, 2016)
  *Automatic Differentiation for Propagation of Orbit Uncertainties in Orekit*
PROJECT ORGANIZATION
**PROJECT ORGANIZATION – PMC**

- **Orekit Project Management Committee (PMC):**
  - **Role:** Strategic planning, code reviewing, vote on new releases and new committers
  - **Newcomer:** Welcome to Yannick Jeandroz (Airbus DS), arrived in Jan 2019!
  - **Members as of May 2019:**
    
    Paul Cefola (University at Buffalo)
    Frank Dreger (European Space Agency - ESOC)
    Nicolas Frouvelle (CS Systèmes d’Information)
    Hank Grabowski (Independent Expert)
    Sébastien Herbinière (Thales Alenia Space)
    Petrus Hyvönen (Swedish Space Corporation)
    Yannick Jeandroz (Airbus Defense and Space)
    Stéphanie Lizy-Destrez (ISAE - Sup’Aéro)
    Luc Maisonobe (CS Systèmes d’Information)
    Guillermo Ortega (European Space Agency - ESTEC)
    Pascal Parraud (CS Systèmes d’Information)
    Evan Ward (Naval Research Laboratory)
• **Git-flow** like branching model (July 2017)

• **Governance update** - Critical bug fixes release (Nov 2017)

• **New forge** - Gitlab (Aug 2018)

• **New forum** - Discourse (Aug 2018)

• **New PMC Member** - Yannick Jeandroz - Airbus DS (Jan 2019)

• **New developer** - Bryan Cazabonne (CS-SI) (Feb 2019)

• **First Merge Requests** (May 2019)
• Since July 2017

• Stability:
  • Select master branch
  • It points to latest release

• Maintain a product:
  • Stick to release x.y
  • It includes patches for x.y

• Want latest features:
  • Follow develop branch
  • It is the « bleeding edge » of the library
• Governance Update (August 2017):
  No more PMC vote delay for urgent security patches
**PROJECT ORGANIZATION – NEW FORGE**

- **Gitlab forge (August 2018):** [https://gitlab.orekit.org/orekit/orekit](https://gitlab.orekit.org/orekit/orekit)

Orekit is a free low level space dynamics library written in Java. It provides basic elements (orbits, dates, attitude, frames, ...) and various algorithms to handle them. Homepage: [http://www.orekit.org/](http://www.orekit.org/)
PROJECT ORGANIZATION – NEW FORUM

- Discourse forum (August 2018): https://forum.orekit.org
PROJECT ORGANIZATION – SOME STATISTICS

- **Discourse forum:** Traffic $\times 2$ compared to former mailing lists !!
  - ~150 subscribers
  - ~170 topics visited/day (2/3 from anonymous users)
  - First answer in less than 17 hours

- **Orekit website traffic:** ~230 visits - 1200 pages – 21 downloads /day

- **Maven repository traffic:**

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![Downloads Over the Last 12 Months For org.orekit](chart.png)
TRENDS: v10.0 & BEYOND
• **Version 10.0: Next major version of Orekit**
  - Will be released soon (June 2019 ?)
  - Based on Hipparchus 1.5

• **Features:**
  - **DSST Orbit Determination**
    - Estimation in **mean** or **osculating elements** for **batch LS & Kalman filter**
    - Presentation: Bryan Cazabonne (see later…)
    - **Publication: Cazabonne B., Maisonobe L.** (ICATT 2018),
      *Open-source Orbit Determination using semi-analytical theory*
  - **Propagation in non-inertial frame**
    - Inertial forces due to frame rotation
    - Propagation in any frame including ITRF, Lagrangian points based frames etc
  - **GNSS specialized propagators:** GPS, Galileo, Glonass, Beidou, QZSS
  - **Documentation improvements:** Readme file, mailmap, building instructions…
  - **Various bug fixes**
• **Toward Precise Orbit Determination:** Long term goal

• **Since version 9**
  - Inter-satellite range measurements (9.0)
  - Antenna Phase Center measurements modifiers (9.0)
  - EOP estimation in precise orbit determination (9.0)
  - Ground station displacements (ocean and solid tides’ loads) (9.1)
  - Loading of RINEX, ANTEX files
  - CODE measurements, phase measurements (basic) (9.2)
  - **Kouba attitude models** (midnight/noon transition for all constellations’ types) (9.2)
  - Tropospheric zenith delay estimation (9.3)
  - Clock offsets estimation (ground-stations & satellite clocks) (9.3)

• **Version 10.0**
  - **Phase measurements** with integer **ambiguity resolution** (lambda method)
  - Ionospheric models: Global Ionosphere map (IONEX files), NeQuick
**TRENDS – FUTURE VERSIONS** (1/2)

- **New Features suggestions**
  - **Precise OD:**
    - Phase measurements’ improvements (M-lambda, wind-up effect etc.)
    - Combined measurements: iono-free…
    - Integration in Orekit OD scheme: tests, cross-validation with available results (IGS files...)
  - **Maneuvers:**
    - Variable thrust maneuvers (future *Airbus contribution!*)
  - **Others:**
    - Better handling of atmospheric models inputs
    - One line element set
    - SPICE Kernel loading
    - ??

**Suggestions from the community are welcome !!**
**TRENDS – FUTURE VERSIONS (2/2)**

- **Project Organization Suggestions**
  - **Forum:** More categories → FAQ, Orekit Python, others?
  - **Forge:**
    - Merge request guide
    - Issue labels re-organization + explanation
    - Nightly builds publication (with Nexus artifact repository) ?
    - Gitlab-CI + SonarQube replacing Jenkins ?
      - Better integration with Gitlab and merge requests
      - Website and Maven static website publication automation
    - Release Process: Automation for easier release
- **Documentation:**
  - More tutorials, new tools for tutorials ? (Jupyter with Java/Python kernels, visualization tools (Cesium) etc.)

**Suggestions from the community are welcome !!**
Thank you for your attention