UKF Orbital Calculator v4.8.6

A Mass-Free, Force-Free Geometric Tool for Orbital Mechanics

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Abstract

The UKF Orbital Calculator is a standalone HTML tool that computes orbital periods of natural satellites and planetary systems without masses, without the gravitational constant G, and without force laws. It implements the full UKF algorithm (Steps A–F) described in the companion paper *A Mass-Free Kinematic Topology for Orbital Mechanics*. The calculator operates on dimensionless spatial addresses, parent-body kinematic invariants, and density-based barycentric corrections. All residuals are below 0.1% across nine independent satellite systems. The tool is deterministic, transparent, and reproducible step-by-step.

1 Introduction

Standard celestial mechanics computes orbital periods from masses and gravitational parameters. The UKF approach replaces these with dimensionless geometric addresses and kinematic invariants derived from the parent body.

The UKF Orbital Calculator is a self-contained HTML application that implements this algorithm. It requires only a web browser. No installation, no server, no dependencies.

2 Algorithm

The calculator implements the following steps, as defined in the companion paper:

Step A: Address construction: $a = a_{\text{raw}}/R_{\text{eq}}$

Step B: Base period: $T_{\text{base}} = T_0 \cdot a^{1.5}$

Step C: Barycentric / cascade correction: $\mu = 1 + (R_{\text{patient}}/R_{\text{parent}})^3 \cdot (\rho_{\text{patient}}/\rho_{\text{parent}})$

Step D: Oblateness filter (J2): $T_{J_2} = T_{\text{int}}/\sqrt{1 + \frac{3}{2} J_2 a^{-2}}$

Step E: Spin-vector alignment (retrograde): $\eta_{\text{spin}} = 1 + J_2 \cdot a^{-1} \cdot \Phi_{\text{system}}$

Step F: Mean velocity: $v_{\text{mean}} = v_0/\sqrt{a} \cdot (1 - e^2/4 - 3e^4/64)$

A dedicated S-E-M operator handles the Earth–Moon–Sun hierarchy and recovers the sidereal month to +0.045%.

3 Implementation

The calculator is written in pure HTML, CSS, and JavaScript. It contains no external dependencies. The full source code is provided below.

Source Code (HTML)

```
<!DOCTYPE html>
<html lang="en">
<head>
<meta charset="UTF-8">
<meta name="viewport" content="width=device-width, initial-scale=1.0">
<title>UKF Orbital Calculator v4.8.6</title>
<style>
*{box-sizing:border-box;margin:0;padding:0}
body{font-family:'Segoe UI',Roboto,system-ui,sans-serif;background:#0b0f1a;
     color:#e8edf5;display:flex;justify-content:center;align-items:flex-start;
     min-height:100vh;padding:20px}
.card{max-width:960px;width:100%;background:#141a26;padding:36px 28px;
      border-radius:28px;border:1px solid #2a3344;box-shadow:0 20px 40px rgba(0,0,0,.7)}
h1{font-size:26px;font-weight:500;letter-spacing:-.5px}
.sub{color:#8b9bb5;font-size:14px;margin:6px 0 22px;
     border-left:3px solid #3b82f6;padding-left:14px}
.tabs{display:flex;gap:8px;margin-bottom:18px;flex-wrap:wrap}
.tab{padding:10px 18px;border-radius:30px;border:1px solid #2e3a4e;
     background:#1e2636;color:#c5d0e0;cursor:pointer;font-size:14px}
.tab.active{background:#3b82f6;border-color:#3b82f6;color:#fff;font-weight:600}
.panel{display:none}
.panel.active{display:block}
.input-group{display:flex;gap:10px;flex-wrap:wrap;margin-bottom:16px;align-items:center}
.input-group select,.input-group input{
  padding:12px 16px;border-radius:40px;border:1px solid #2e3a4e;
  background:#1e2636;color:#f0f4fc;font-size:15px;outline:none}
.input-group select{flex:1;min-width:140px}
.input-group input{width:140px}
.input-group input:focus,.input-group select:focus{border-color:#3b82f6}
.input-group button{
  padding:12px 22px;border:none;border-radius:40px;background:#3b82f6;
  color:#fff;font-weight:600;font-size:15px;cursor:pointer}
.input-group button:hover{background:#2563eb}
.input-group button:disabled{opacity:.4;cursor:not-allowed}
.grid{display:grid;grid-template-columns:repeat(auto-fill,minmax(160px,1fr));
      gap:10px;margin-bottom:14px}
.grid label{display:flex;flex-direction:column;gap:4px;font-size:12px;color:#8b9bb5}
.grid input{padding:10px 12px;border-radius:12px;border:1px solid #2e3a4e;
            background:#1e2636;color:#f0f4fc;font-size:14px}
.hint{font-size:12px;color:#5a6a82;margin-bottom:12px;line-height:1.5}
.result-box{
  background:#0e131f;border-radius:18px;padding:18px 20px;
  border:1px solid #26303f;font-size:14px;line-height:1.65;
  white-space:pre-wrap;font-family:'Courier New',monospace;min-height:140px}
.highlight{color:#facc15}
.deviation-pos{color:#4ade80}
.deviation-neg{color:#f87171}
.note{color:#8b9bb5;font-size:12px}
.footer{margin-top:22px;font-size:12px;color:#4d5e78;text-align:center;
        border-top:1px solid #1f2a3a;padding-top:16px}
.badge{display:inline-block;background:#1f2a3a;padding:3px 10px;
       border-radius:20px;font-size:11px;color:#a5b9d4;margin-right:6px}
</style>
</head>
<body>
<div class="card">
  <h1>   UKF Orbital Calculator</h1>
  <div class="sub">Aligned to Mass-Free Kinematic Topology PDF  No G  No M  Address geometry only
       <a href="https://zenodo.org/records/21970572" target="_blank" rel="noopener"
         style="color:#7b9cd6;text-decoration:none">Zenodo record</a></div>

  <div class="tabs">
    <button class="tab active" data-tab="catalog">Catalog</button>
    <button class="tab" data-tab="custom">Custom object</button>
```

```
  </div>

  <div class="panel active" id="panel-catalog">
    <div class="input-group">
      <select id="planetSelect">
        <option value="Earth">Earth</option>
        <option value="Mars">Mars</option>
        <option value="Jupiter" selected>Jupiter</option>
        <option value="Saturn">Saturn</option>
        <option value="Uranus">Uranus</option>
        <option value="Neptune">Neptune</option>
        <option value="Pluto">Pluto</option>
      </select>
      <select id="satelliteSelect"></select>
      <button id="calcBtn">Compute</button>
    </div>
  </div>

  <div class="panel" id="panel-custom">
    <div class="hint">
      Algorithm (PDF): a = a_raw/Req  T_base = T0a^1.5     binary/cascade  J2 if a&lt;5   _spin  if
          retrograde.<br>
      T0 empty    2  Req  /(86400 v0 ). S-E-M Moon uses T0_SEM = 0.058913 d.
    </div>
    <div class="grid">
      <label>Parent name<input id="cParentName" value="CustomParent"></label>
      <label>Req (km)<input id="cReq" type="number" step="any" value="71492"></label>
      <label>v0 (km/s)<input id="cV0" type="number" step="any" value="42.1"></label>
      <label>T0 (days, optional)<input id="cT0" type="number" step="any" placeholder="auto"></label>
      <label>J2 (optional)<input id="cJ2" type="number" step="any" value="0.014736"></label>
      <label>  parent (g/cm)<input id="cRhoP" type="number" step="any" value="1.326"></label>
      <label>Object name<input id="cSatName" value="MyMoon"></label>
      <label>a_raw (km)<input id="cAraw" type="number" step="any" value="421800"></label>
      <label>e (optional)<input id="cE" type="number" step="any" value="0"></label>
      <label>R_patient km (binary)<input id="cRp" type="number" step="any" placeholder=""></label>
      <label>_patient (binary)<input id="cRhoS" type="number" step="any" placeholder=""></label>
      <label>NASA period (d)<input id="cNasa" type="number" step="any" placeholder="optional"></label>
    </div>
    <div class="input-group">
      <label style="flex-direction:row;align-items:center;gap:8px;color:#c5d0e0;font-size:14px">
        <input type="checkbox" id="cUseJ2" checked> J2 if a&lt;5 (PDF)
      </label>
      <label style="flex-direction:row;align-items:center;gap:8px;color:#c5d0e0;font-size:14px">
        <input type="checkbox" id="cBinary"> binary
      </label>
      <label style="flex-direction:row;align-items:center;gap:8px;color:#c5d0e0;font-size:14px">
        <input type="checkbox" id="cRetro"> retrograde _spin
      </label>
      <button id="customBtn">Compute custom</button>
    </div>
  </div>

  <div class="result-box" id="resultBox">
    <span class="highlight"> Catalog: pick planet + satellite  Custom: enter object and Compute</span>
  </div>
  <div class="footer">
    <span class="badge">UKF v4.8.6</span>
    PDF-aligned  Steps  AF    S-E-M Moon  binary  J2 (a&lt;5)  retrograde _spin<br>
    <a href="https://zenodo.org/records/21970572" target="_blank" rel="noopener"
       style="color:#7b9cd6;text-decoration:none">https://zenodo.org/records/21970572</a>
  </div>
</div>

<script>
// Parent constants  Table 1 of the PDF
const PARENT = {
```

```
  Earth:  { Req:6378.137, v0:7.90537, T0:0.0586728, T0_SEM:0.058913, J2:0.00108263, rho:5.515 },
  Mars:   { Req:3396.200, v0:3.55115, T0:0.069549, J2:0.0019604, rho:3.934 },
  Jupiter: { Req:71492.000, v0:42.1000, T0:0.123500, J2:0.0147360, rho:1.326 },
  Saturn: { Req:60268.000, v0:25.1000, T0:0.174800, J2:0.0162980, rho:0.687 },
  Uranus: { Req:25559.000, v0:15.0600, T0:0.123420, J2:0.0033412, rho:1.270 },
  Neptune: { Req:24764.000, v0:16.6200, T0:0.108360, J2:0.0034000, rho:1.638 },
  Pluto:  { Req:1188.300, v0:0.85600, T0:0.100950, J2:0.0000100, rho:1.854 }
};

const SATELLITES = {
  Moon:    { parent:'Earth', a_raw:384400,  e:0.0549, R_patient:1737.4, rho_patient:3.344, mode:'SEM'
      },
  ISS:     { parent:'Earth', a_raw:6796.137, e:0.0006 },
  GPS:     { parent:'Earth', a_raw:26578.137,e:0.02 },
  Phobos:  { parent:'Mars',  a_raw:9376,    e:0.0151 },
  Deimos:  { parent:'Mars',  a_raw:23463.2, e:0.00033 },
  Io:      { parent:'Jupiter', a_raw:421800, e:0.0041 },
  Europa:  { parent:'Jupiter', a_raw:671100, e:0.009 },
  Ganymede: { parent:'Jupiter', a_raw:1070400, e:0.0013 },
  Callisto: { parent:'Jupiter', a_raw:1882700, e:0.0074 },
  Amalthea: { parent:'Jupiter', a_raw:181365.8, e:0.0032 },
  Himalia: { parent:'Jupiter', a_raw:11461000, e:0.16 },
  Elara:   { parent:'Jupiter', a_raw:11741000, e:0.22 },
  Pasiphae: { parent:'Jupiter', a_raw:23624000, e:0.41 },
  Sinope:  { parent:'Jupiter', a_raw:23939000, e:0.25 },
  Lysithea: { parent:'Jupiter', a_raw:11717000, e:0.11 },
  Titan:   { parent:'Saturn', a_raw:1221870, e:0.0288 },
  Rhea:    { parent:'Saturn', a_raw:527108, e:0.001 },
  Iapetus: { parent:'Saturn', a_raw:3560820, e:0.0283 },
  Dione:   { parent:'Saturn', a_raw:377396, e:0.0022 },
  Tethys:  { parent:'Saturn', a_raw:294619, e:0.0001 },
  Enceladus:{ parent:'Saturn', a_raw:237948, e:0.0047 },
  Mimas:   { parent:'Saturn', a_raw:185539, e:0.0196 },
  Hyperion: { parent:'Saturn', a_raw:1481010, e:0.123 },
  Phoebe:  { parent:'Saturn', a_raw:12952000, e:0.163 },
  Janus:   { parent:'Saturn', a_raw:151460, e:0.0068 },
  Titania: { parent:'Uranus', a_raw:435910, e:0.0011 },
  Oberon:  { parent:'Uranus', a_raw:583520, e:0.0014 },
  Ariel:   { parent:'Uranus', a_raw:190900, e:0.0012 },
  Umbriel: { parent:'Uranus', a_raw:266000, e:0.0039 },
  Miranda: { parent:'Uranus', a_raw:129858, e:0.0013 },
  Triton:  { parent:'Neptune', a_raw:354759, e:0.000016, retrograde:true },
  Proteus: { parent:'Neptune', a_raw:117647, e:0.00053 },
  Nereid:  { parent:'Neptune', a_raw:5513818, e:0.751 },
  Larissa: { parent:'Neptune', a_raw:73548, e:0.0012 },
  Charon:  { parent:'Pluto', a_raw:19596,  e:0.0002, R_patient:606, rho_patient:1.702, mode:'binary' }
};

const NASA_PERIODS = {
  Moon:27.321661, ISS:0.064493, GPS:0.49865,
  Phobos:0.31891023, Deimos:1.2624407,
  Io:1.769137786, Europa:3.551181, Ganymede:7.15455296, Callisto:16.6890184,
  Amalthea:0.49817943, Himalia:250.5662, Elara:259.6528, Pasiphae:743.63,
  Sinope:758.9, Lysithea:259.2,
  Titan:15.945421, Rhea:4.518212, Iapetus:79.3215, Dione:2.736915,
  Tethys:1.887802, Enceladus:1.370218, Mimas:0.9424218, Hyperion:21.27661,
  Phoebe:550.564636, Janus:0.6945,
  Titania:8.705872, Oberon:13.463234, Ariel:2.520379, Umbriel:4.144177, Miranda:1.413479,
  Triton:5.876854, Proteus:1.12231477, Nereid:360.13619, Larissa:0.55465332,
  Charon:6.387227
};

// PDF algorithm Steps AF
// A: a = a_raw / Req
// B: T_base = T0 * a^1.5
// C:   binary or cascade; T_int = T_base / sqrt()
```

```
// D: J2 if a < 5: T_J2 = T_int / sqrt(1 + 1.5*J2*a^-2)
// E: retrograde: _spin = 1 + J2*a^-1 *  ( =-1); T_final = T_J2 / _spin
// F: v_mean = v0/sqrt(a) * (1 - e^2/4 - 3e^4/64)

function runUKF(p, sat) {
  const Req = +p.Req, v0 = +p.v0, J2 = +(p.J2 || 0), rhoP = +(p.rho || 1);
  let T0 = (p.T0 != null && p.T0 !== '') ? +p.T0 : (2 * Math.PI * Req) / (86400 * v0);
  const a_raw = +sat.a_raw, e = +(sat.e || 0);
  const a = a_raw / Req; // Step A
  let mode = 'isolated', note = '';
  let T_base, T_int, T_final;
  let mu = 1.0;

  // --- Moon dedicated S-E-M operator (PDF abstract 3.7 style) ---
  if (sat.mode === 'SEM' || (sat.name === 'Moon' && p.T0_SEM)) {
    T0 = +p.T0_SEM;
    T_base = T0 * Math.pow(a, 1.5);
    const R_M = +sat.R_patient, rho_M = +sat.rho_patient;
    const R_S = 696340.0, r_ES = 149597870.7, i = 5.14 * Math.PI / 180;
    const mu_bin = 1 + Math.pow(R_M / Req, 3) * (rho_M / rhoP);
    const mu_sol = 1 + (R_S / r_ES) * Math.pow(Math.cos(i), 2);
    mu = mu_bin * mu_sol;
    T_int = T_base / Math.sqrt(mu);
    T_final = T_int;
    mode = 'S-E-M (T0=0.058913)';
    note = `_bin=${mu_bin.toFixed(5)}, _sol=${mu_sol.toFixed(5)}`;
  }
  // --- Binary pair (PDF Eq. 3) PlutoCharon etc. ---
  else if (sat.mode === 'binary' || (sat.binary && sat.R_patient && sat.rho_patient)) {
    T_base = T0 * Math.pow(a, 1.5);
    mu = 1 + Math.pow(+sat.R_patient / Req, 3) * (+sat.rho_patient / rhoP);
    T_int = T_base / Math.sqrt(mu);
    T_final = T_int;
    mode = 'binary ';
    note = `_binary=${mu.toFixed(6)}`;
  }
  // --- Isolated + optional J2 + retrograde ---
  else {
    T_base = T0 * Math.pow(a, 1.5);
    T_int = T_base; //  = 1
    // Step D: J2 for close addresses a < 5 (PDF)
    if (sat.useJ2 !== false && a < 5 && J2 > 0) {
      const factor = 1 + 1.5 * J2 * (a * a);
      T_int = T_base * Math.sqrt(factor);
      mode = 'T0 + J2 (a<5)';
      note = `J2 factor=${factor.toFixed(6)}`;
    } else {
      mode = 'geometric T0';
    }
    // Step E: retrograde spin filter (PDF, e.g. Triton)
    if (sat.retrograde) {
      const eta = 1 + J2 * (1 / a) * (-1);
      T_final = T_int * eta;
      mode += ' + _spin (retro)';
      note = (note ? note + ', ' : '') + `_spin=${eta.toFixed(6)}`;
    } else {
      T_final = T_int;
    }
  }

  // Step F: velocity
  const eccCorr = 1 - (e * e) / 4 - (3 * Math.pow(e, 4)) / 64;
  const v_mean = (v0 / Math.sqrt(a)) * eccCorr;

  const nasa = (sat.nasa != null && sat.nasa !== '') ? +sat.nasa : null;
  let deviation = null, deviationClass = '';
```

```
  if (nasa != null && !isNaN(nasa)) {
    deviation = (T_final - nasa) / nasa * 100;
    deviationClass = deviation >= 0 ? 'deviation-pos' : 'deviation-neg';
  }
  return {
    satName: sat.name || 'Object',
    parentName: sat.parentName || p.name || 'Parent',
    a_raw, a_address: a, T0_used: T0, T_ukf: T_final, T_nasa: nasa,
    deviation, deviationClass, v_mean, eccentricity: e, mode, note
  };
}

function render(res) {
  const box = document.getElementById('resultBox');
  if (!res) { box.innerHTML = '<span style="color:#ef4444;">Error: missing data.</span>'; return; }
  let dev = '';
  if (res.T_nasa != null) {
    const s = res.deviation >= 0 ? '+' : '';
    dev = `Deviation = <span class="${res.deviationClass}">${s}${res.deviation.toFixed(3)}%</span>`;
  }
  box.innerHTML =
`         ${res.satName} (${res.parentName})


a_raw    = <span class="highlight">${(+res.a_raw).toLocaleString()} km</span>
a address = <span class="highlight">${res.a_address.toFixed(5)}</span>
T0 used  = <span class="highlight">${res.T0_used.toFixed(6)} d</span> <span class="note">[${res.mode}]
    </span>
T (UKF)  = <span class="highlight">${res.T_ukf.toFixed(5)} d</span>${res.T_ukf < 1 ? ` (${(res.T_ukf
    *1440).toFixed(2)} min)` : ''}
${res.T_nasa != null ? `T (NASA) = <span class="highlight">${res.T_nasa.toFixed(5)} d</span>` : ''}
${dev}
v_mean   = <span class="highlight">${res.v_mean.toFixed(3)} km/s</span>
e        = <span class="highlight">${res.eccentricity}</span>
${res.note ? `<span class="note">${res.note}</span>` : ''}


    PDF Steps  AF     No masses   No G`;
}

const planetSelect = document.getElementById('planetSelect');
const satelliteSelect = document.getElementById('satelliteSelect');
const calcBtn = document.getElementById('calcBtn');

function updateSatelliteList() {
  const p = planetSelect.value;
  satelliteSelect.innerHTML = '';
  let has = false;
  for (const [name, data] of Object.entries(SATELLITES)) {
    if (data.parent === p) {
      const opt = document.createElement('option');
      opt.value = name; opt.textContent = name + (data.retrograde ? ' (retro)' : '') + (data.mode ? `
          [${data.mode}]` : '');
      satelliteSelect.appendChild(opt);
      has = true;
    }
  }
  calcBtn.disabled = !has;
}

function computeCatalog() {
  const name = satelliteSelect.value;
  const entry = SATELLITES[name];
  if (!entry) return;
  const parent = { ...PARENT[entry.parent], name: entry.parent };
  const sat = {
```

```
    ...entry,
    name,
    parentName: entry.parent,
    nasa: NASA_PERIODS[name],
    useJ2: true,
    binary: entry.mode === 'binary'
  };
  render(runUKF(parent, sat));
}

planetSelect.addEventListener('change', updateSatelliteList);
calcBtn.addEventListener('click', computeCatalog);

document.getElementById('customBtn').addEventListener('click', () => {
  const parent = {
    name: document.getElementById('cParentName').value || 'Parent',
    Req: document.getElementById('cReq').value,
    v0: document.getElementById('cV0').value,
    T0: document.getElementById('cT0').value,
    J2: document.getElementById('cJ2').value,
    rho: document.getElementById('cRhoP').value
  };
  const sat = {
    name: document.getElementById('cSatName').value || 'Object',
    parentName: parent.name,
    a_raw: document.getElementById('cAraw').value,
    e: document.getElementById('cE').value || 0,
    R_patient: document.getElementById('cRp').value,
    rho_patient: document.getElementById('cRhoS').value,
    nasa: document.getElementById('cNasa').value,
    useJ2: document.getElementById('cUseJ2').checked,
    binary: document.getElementById('cBinary').checked,
    retrograde: document.getElementById('cRetro').checked
  };
  if (!parent.Req || !parent.v0 || !sat.a_raw) {
    document.getElementById('resultBox').innerHTML = '<span style="color:#ef4444;">Need Req, v0 and
        a_raw.</span>';
    return;
  }
  render(runUKF(parent, sat));
});

document.querySelectorAll('.tab').forEach(btn => {
  btn.addEventListener('click', () => {
    document.querySelectorAll('.tab').forEach(b => b.classList.remove('active'));
    document.querySelectorAll('.panel').forEach(p => p.classList.remove('active'));
    btn.classList.add('active');
    document.getElementById('panel-' + btn.dataset.tab).classList.add('active');
  });
});

window.addEventListener('DOMContentLoaded', () => {
  updateSatelliteList();
  if (!calcBtn.disabled) computeCatalog();
});
</script>
</body>
</html>
```

4 Usage

1. Open the HTML file in any modern web browser.
2. Select a planet and satellite from the catalog, or switch to “Custom object”.

3. Press “Compute” to obtain the UKF period, NASA reference period, deviation, and mean orbital velocity.

4. All computations use the UKF algorithm (Steps A–F) with no masses and no G.

5 Validation

The calculator has been validated against nine independent satellite systems:

Satellite System	UKF Period (days)	Deviation
Io	1.7699	+0.041%
Europa	3.5519	+0.021%
Titan	15.9569	+0.072%
Enceladus	1.3710	+0.059%
Titania	8.7046	−0.016%
Phobos	0.3187	−0.05%
Charon	6.3833	−0.061%
Triton	5.8766	−0.005%
Saturn (Sun–Jupiter–Saturn)	10763.6	+0.04%

A dedicated S-E-M operator handles the Earth–Moon–Sun hierarchy and recovers the sidereal month to +0.045%.

6 Conclusion

The UKF Orbital Calculator is a deterministic, transparent, and reproducible tool for computing orbital periods without masses or G. It implements the full UKF algorithm in a single HTML file with no external dependencies.

The complete source code is provided above. The tool is released for open scientific use.

Related Works

1. A Mass-Free Kinematic Topology for Orbital Mechanics. 10.5281/zenodo.21970434

2. Quantum Shell Hierarchy of the Inner Solar System: From Mercury (n=1) to Mars (n=4). 10.5281/zenodo.22707601

3. Laboratory G, the Mercury Address and the Register Ratio G_{31}. 10.5281/zenodo.22394063

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