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Constellation Deployment Analysis

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Outline

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- Walker constellation basics
- Design problem
- Analysis method
- Automated scenario generation
- Results
- Extending the problem, next-step analysis, and more results

Walker Constellations Basics

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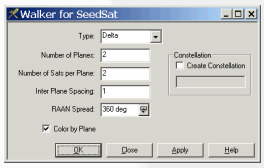
- What is unique about the Walker constellation?
  - Circular orbits have same inclination and period
  - Satellites distributed equally among orbital planes
- Constellation parameters
  - N = number of satellites
  - P = number of planes
  - F = inter plane spacing
  - RAAN spread



Screen shot of STK Walker tool: As shown, STK inserts a 4/2/1 constellation at inclination and period of the "seed satellite".

Walker Constellations

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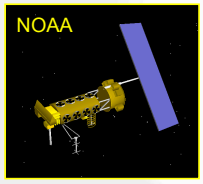

- Advantages
  - Uniform coverage over Earth's surface
- Applications
  - Weather, communications, imaging, navigation
- Examples
  - Commercial: Iridium, Globalstar
  - Military: GPS
  - Scientific: NASA, **NOAA**

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Problem Description

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- A satellite system will use 18 satellites in a Walker configuration.
- Determine which configuration is the "best":
  - Examine gaps in access to the constellation
  - Access to constellation defined as access to at least one sensor.

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Problem Definition

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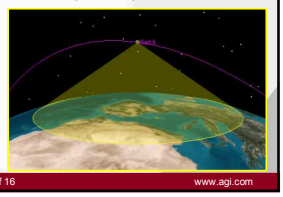
- Design constraints:
  - Satellite altitude = 1000 km
  - Sensor
    - Beam half angle = 55 degrees
    - Fixed pointing at 90 degrees elevation
  - Constellation
    - RAAN spread = 360
    - Inter plane spacing = 2
- Design variables:
  - Number of planes, P
  - Orbit inclination, I
- Vary I and P:
  - I = { 35, 40, 45, 50, 55 }
  - P = { 3, 6, 9 }



Analysis Approach

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- Build a scenario for each of the potential Walker configurations under consideration (15 scenarios)
- Run scenarios and generate output
  - STK reports: minimum, maximum, and average access gaps for a user at a given latitude(s)
  - STK graphics: 2D & 3D animations, snapshots, graphs
- Examine results to identify the best Walker constellation

Building the Scenarios

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- Do NOT attempt to build 15 scenarios manually
  - Time consuming
  - Error prone
  - Difficult (impossible?) to reproduce
- Automate the process with STK/Connect by taking advantage of the similarities in scenarios and iterative nature of the combinations of design variables

Automated Scenario Generation

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INPUT: List of 15 scenarios

AGIUC_I35_N18_P9_F2.sc
AGIUC_I35_N18_P6_F2.sc
AGIUC_I35_N18_P3_F2.sc
AGIUC_I40_N18_P9_F2.sc
AGIUC_I40_N18_P6_F2.sc
AGIUC_I40_N18_P3_F2.sc
AGIUC_I45_N18_P9_F2.sc
AGIUC_I45_N18_P6_F2.sc
AGIUC_I45_N18_P3_F2.sc
AGIUC_I50_N18_P9_F2.sc
AGIUC_I50_N18_P6_F2.sc
AGIUC_I50_N18_P3_F2.sc
AGIUC_I55_N18_P9_F2.sc
AGIUC_I55_N18_P6_F2.sc
AGIUC_I55_N18_P3_F2.sc

Generate file of STK Connect commands. For each scenario in the list…

1. Open the new scenario
2. Insert the seed satellite
3. Set the orbital parameters
4. Build a Walker Constellation
5. Insert a target
6. Insert a chain and add objects
7. Compute chain access
8. Generate report

Run the file using STK Connect interface

OUTPUT: 15 STK scenarios and numerical results

Results

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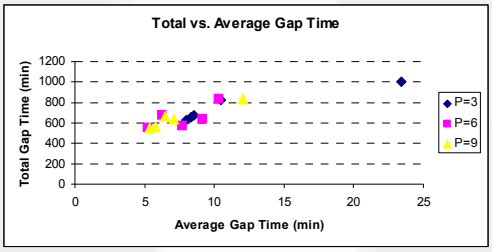

Optimum Configuration: 18/6/2

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Further Analysis

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- The best Walker constellation (18/6/2) has been identified.
  - Shortest average and total gap times
- What is the optimum launch configuration?
  - Maximize the system's coverage during the intermediate stages of deployment

Problem Definition

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- Design constraints
  - 18/6/2 Walker constellation
  - Satellites are launched in groups of three
- Design variable: launch order
  - Distributed: Satellites distributed evenly across planes
  - Sequential: Satellites distributed to one plane at a time

Deployment Approaches

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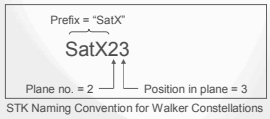
Sequential

- Fill one plane at a time
- Flight schedule
  - Launch 1: SatX11, SatX12, SatX13
  - Launch 2: SatX21, SatX22, SatX23
  - Launch 3: SatX31, SatX32, SatX33
  - Launch 4: SatX41, SatX42, SatX43
  - Launch 5: SatX51, SatX52, SatX53
  - Launch 6: SatX61, SatX62, SatX63

Distributed

- Launch one satellite to each plane
- Flight schedule
  - Launch 1: SatX11, SatX21, SatX31
  - Launch 2: SatX41, SatX51, SatX61
  - Launch 3: SatX12, SatX22, SatX32
  - Launch 4: SatX42, SatX52, SatX62
  - Launch 5: SatX13, SatX23, SatX33
  - Launch 6: SatX43, SatX53, SatX63



STK Naming Convention for Walker Constellations

Analysis Approach

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- Build a scenario for each intermediate stage of deployment for each of the two flight schedules
  - Total of 12 scenarios
- Generate reports from each scenario and compile data to give a clear comparison.
- And remember: Do NOT attempt to build manually. Automate!

Results

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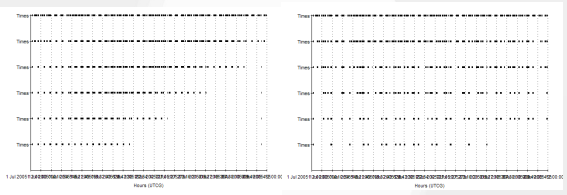
- Constellation Access



Sequential Distributed

Conclusion

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- The advantage of using STK and this automated method of analysis
  - Fast
  - Reduces chance of error in calculation
  - Framework is established for subsequent changes to design constraints
- Avoid custom scripting by using STK/Analyzer