Integrated Mission Planning and Trajectory Simulation Tools for the ULDB Program

Dr. Matthew Kuperus Heun

Global Aerospace Corporation

ULDB Technology Conference

24-25 June 1997

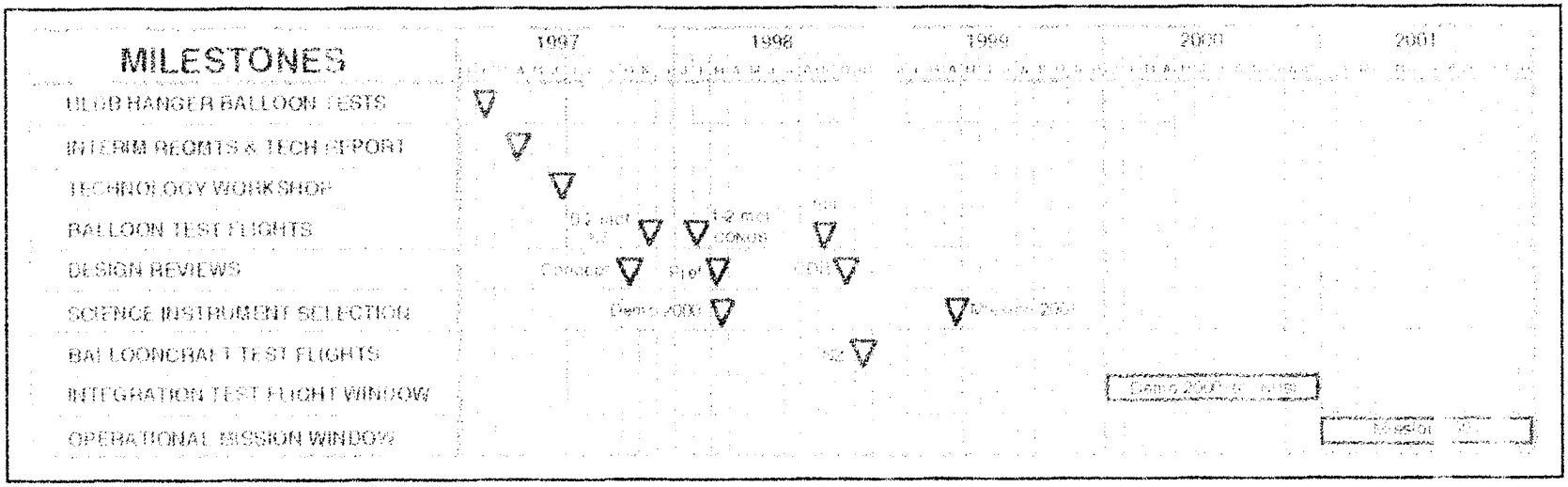
Outline

- ULDB Program
- Trajectory Simulation
- Planning
  - Program
  - Mission
  - Operations
- Integration of Planning and Trajectory Simulation
- Capabilities and Experience of Global Aerospace Corporation

ULDB Program Scope

- Key Program Features
  - Long Duration Missions
  - Multiple Global Circumnavigations
  - High-altitude Science
- Program Requirements
  - ~ 1 ton Scientific Payload
  - ~ 100-day Flights
  - 2 mbar ≤ P ≤ 10 mbar (30 km ≤ z ≤ 43 km)
  - Balloncraft Recovery
- Program Needs
  - Program and Mission Planning Tools
  - Predict-ahead Trajectory Modeling
  - Trajectory Control
  - Method of Evaluating Recovery Requirements
  - Long-duration Balloon Envelopes
  - Long-duration Power Systems

ULDB Program Key Dates



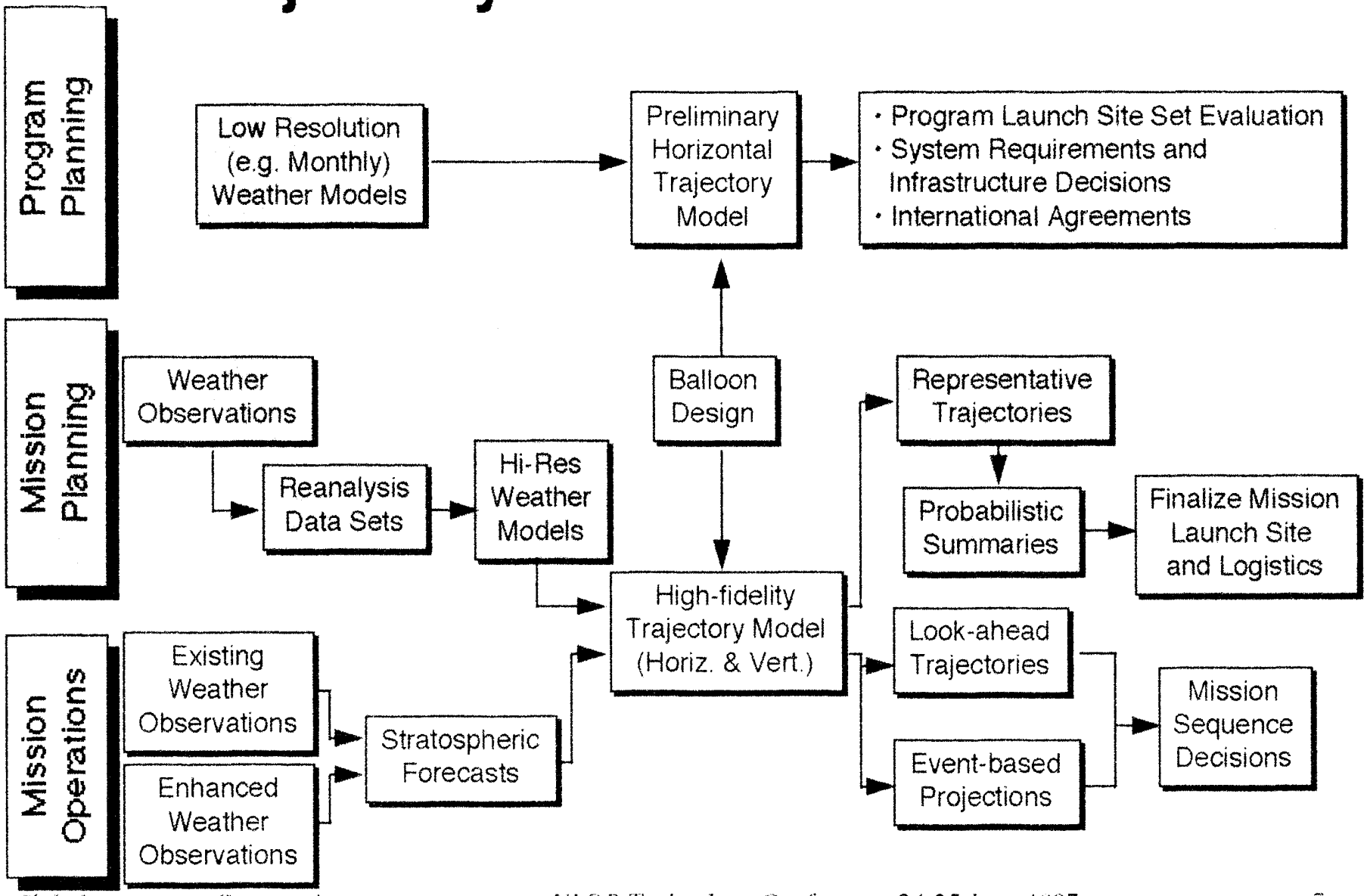
Integrated Mission Planning and Trajectory Simulation Tool

- Core Element is Trajectory Model (Horizontal and Vertical)
  - Event-based Flight Modeling
  - Component-based Balloon Model
  - Probabilistic Summary of Model Results
- Benefits of Tools
  - Evaluation of Launch Sites and Launch Dates
  - Investigate Coupling between Science Opportunities and Trajectories
  - Study Safety Considerations
  - Compare Trajectory Control and Termination Options
  - Useful for Program & Mission Planning and Flight Operations
- Key Element
  - Quality Weather Information

Planning Stages

- Program Planning (Years)
  - Define Science Requirements
  - Define Balloncraft Requirements
  - Select Program Launch Sites and Allocate Resources
  - Define Trajectory Control Requirements
- Mission Planning (Years to Months)
  - Select Science Instruments for Specific Flights or Campaigns
  - Select and Integrate Balloncraft Components
  - Select Launch Sites for Specific Flights
  - Select Trajectory Control for Specific Flights
- Mission Operations (Weeks to Days)
  - Select Launch Date and Time
  - Record Scientific Data and Monitor Health of Balloncraft
  - Decide Cutdown Time
  - Make Trajectory Control Decisions if Possible

Trajectory Simulation Process



Weather Models and Modeling

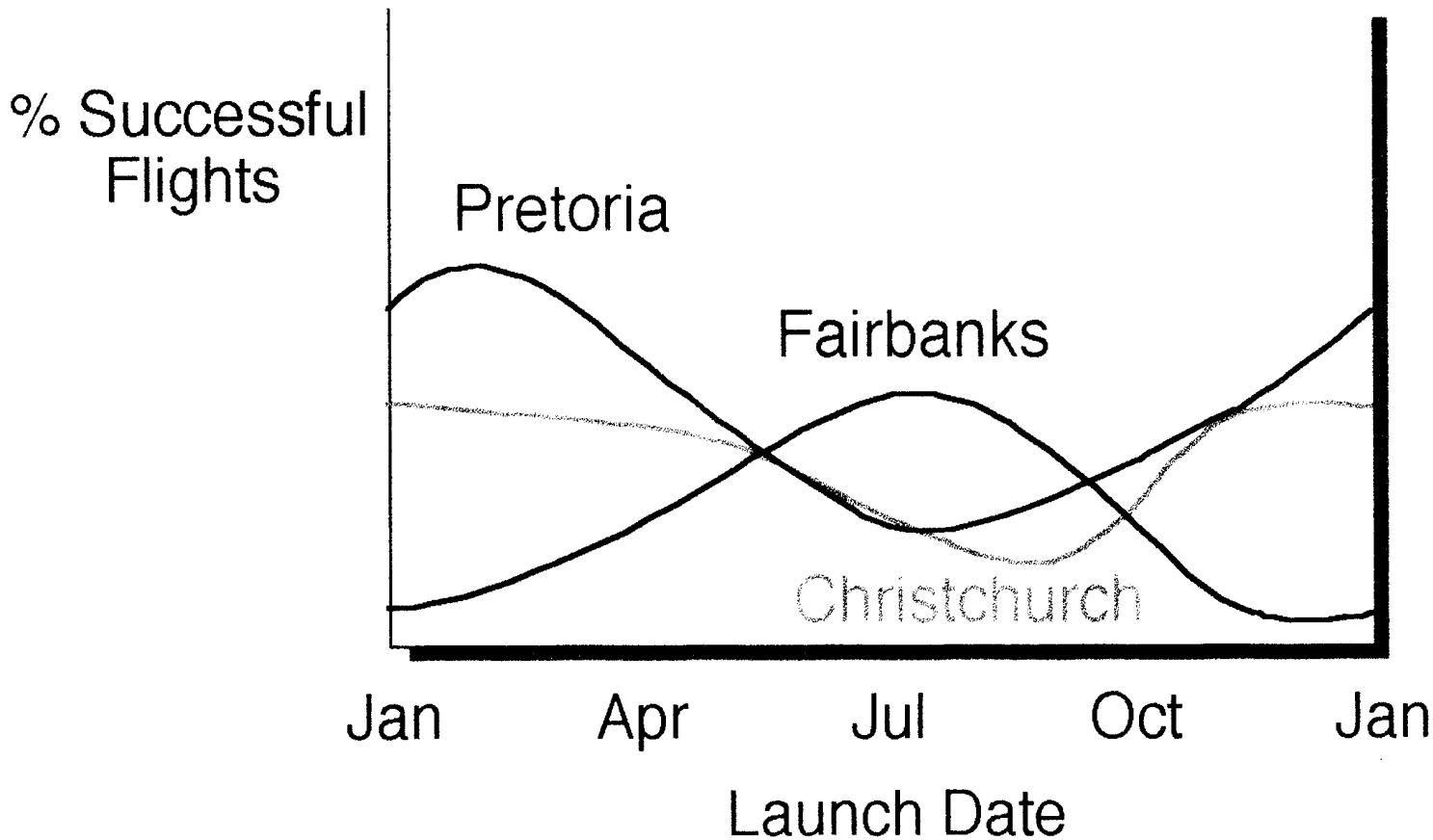
- Reanalysis Data Sets
  - Useful for Representative Trajectories
  - Typically P ≥ 10 mbar, Some Data Sets P ≥ 1 mbar
  - Zonal Flows Typically Reported, Meridional Flows Available Upon Request
- Short-range Stratospheric Forecasts
  - Useful for Mission Operations
  - "Do Not Exist", —Bill Randel of NCAR
- Climate Models
  - May Be Inappropriate for ULDB
  - Low Spatial and Temporal Resolution
  - Used for Greenhouse Effect and Ozone Depletion

Program Planning Issues

- Infrastructure
  - Selecting Set of Launch Sites for Program
  - Allocating Resources for Launch and Recovery Logistics
  - Weather Information Requirements (Additional and/or Enhanced Observations?)
- Balloncraft System Requirements
  - Power System Requirements
  - Recovery and Safety Requirements
  - Flight Profile
    - Science Performance Couples with Trajectory
    - Is Trajectory Control Necessary?
    - Trajectory Control System Requirements
    - Selection of Trajectory Control System Design
- International Agreements

Launch Site Evaluation

Example Flight-success Analysis



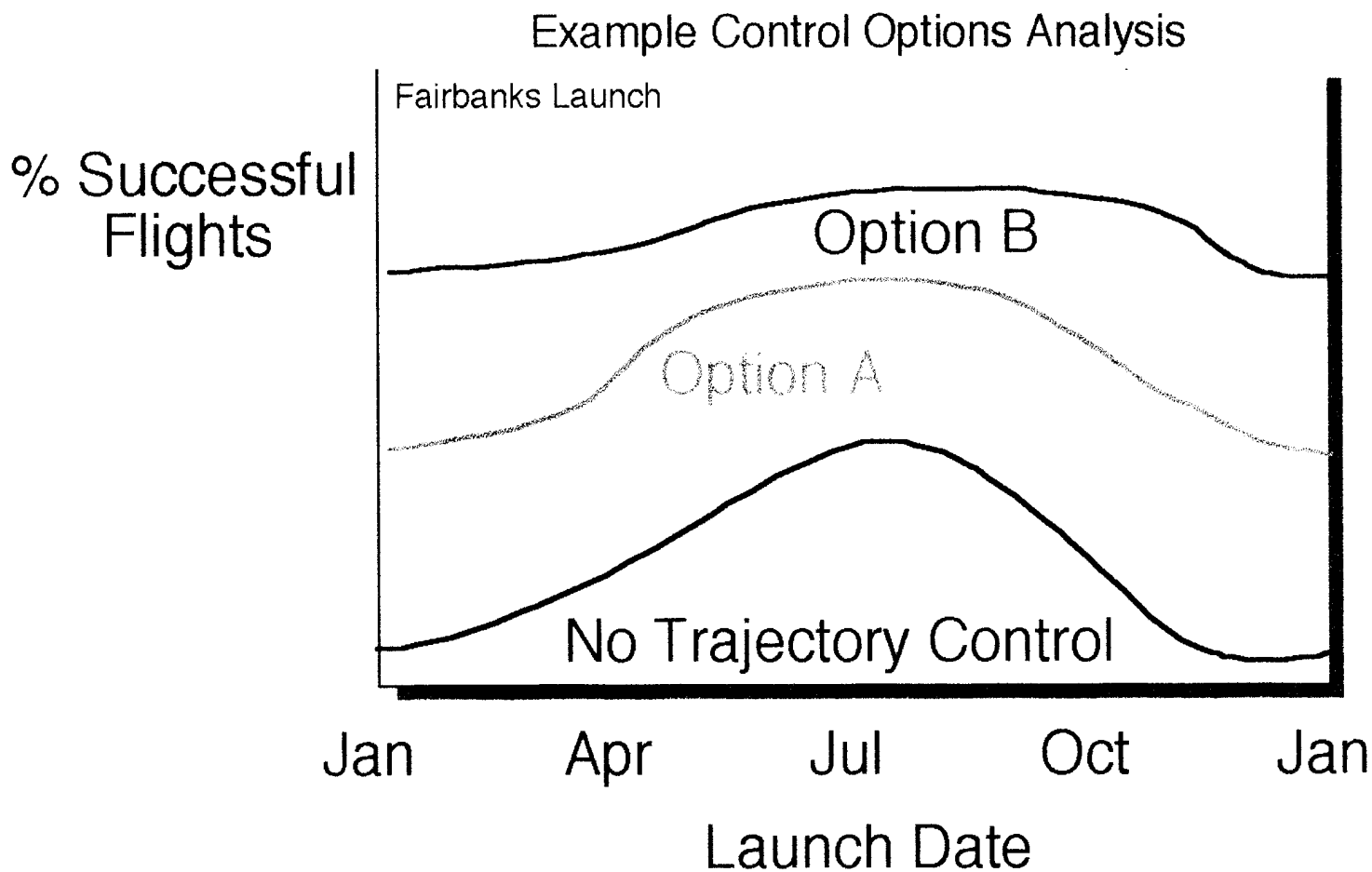
Mission Planning Issues

- Mission Launch Site Selection
  - Meet Science Requirements
  - Meet Recovery Requirements
  - Maximize Probability of Success
- Coupling Between Science and Trajectory
  - Design of Feasible Mission Sequences
  - Optimization of Power Generation and Use Profiles
  - Trajectory Defines Thermal Environment for Balloncraft
- Trajectory Control Evaluation
  - Mission Science Performance
  - Launch Site Selection Impact

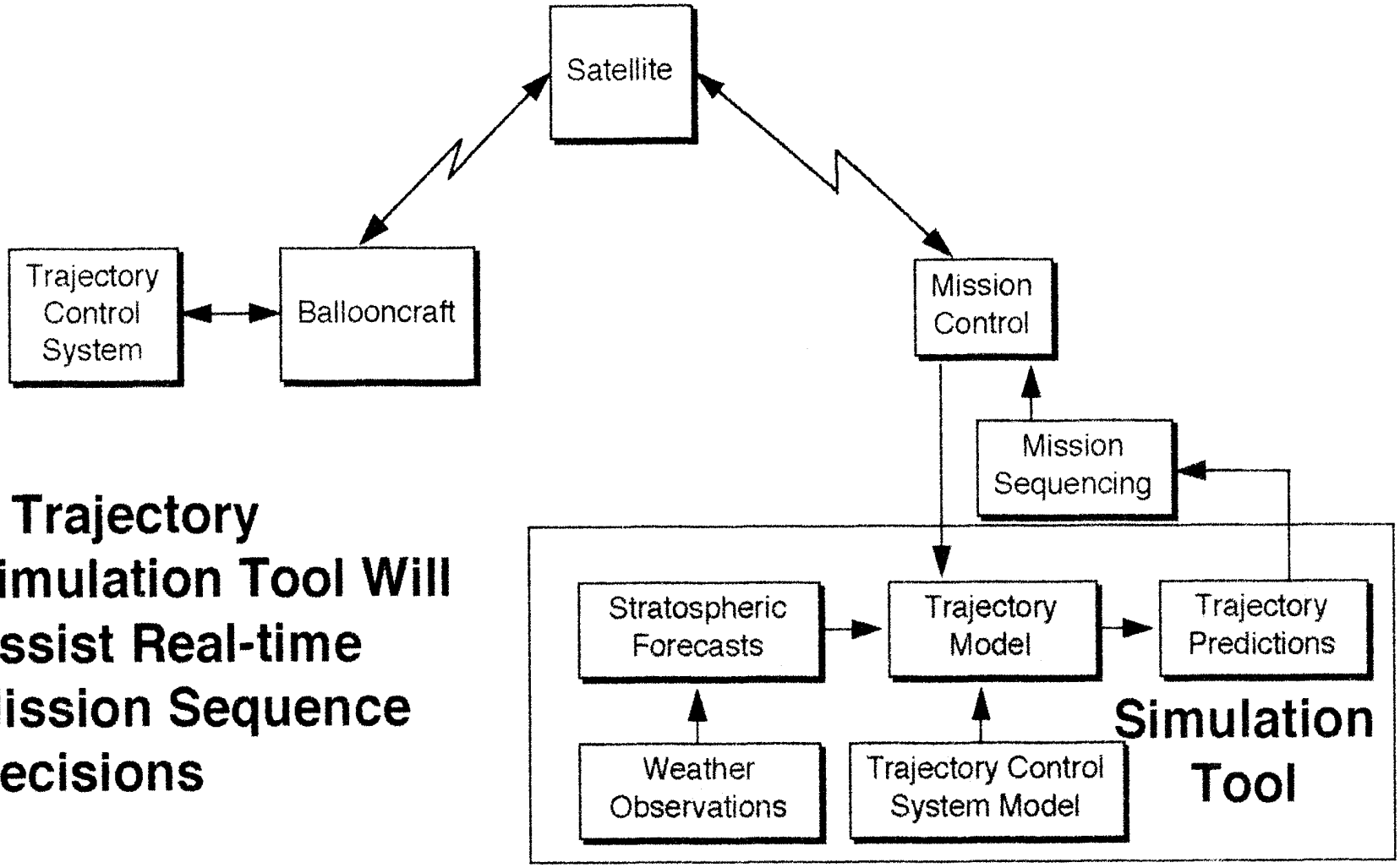
Trajectory Control

- Trajectory Control May Require High-quality Wind Information at Float Altitudes
- Trajectory Model will Provide Instant, Probabilistic Evaluation of Trajectory Control System Efficacy
  - Multiple Simulated Flights
  - Compare Simulations Against "Successful" Flight
    - Avoidance of Certain Countries
    - Allow Cutdown at 100 ± 4 days Over Land
- Global Aerospace Corporation has Proprietary Technology for Trajectory Control Systems

Trajectory Control Evaluation

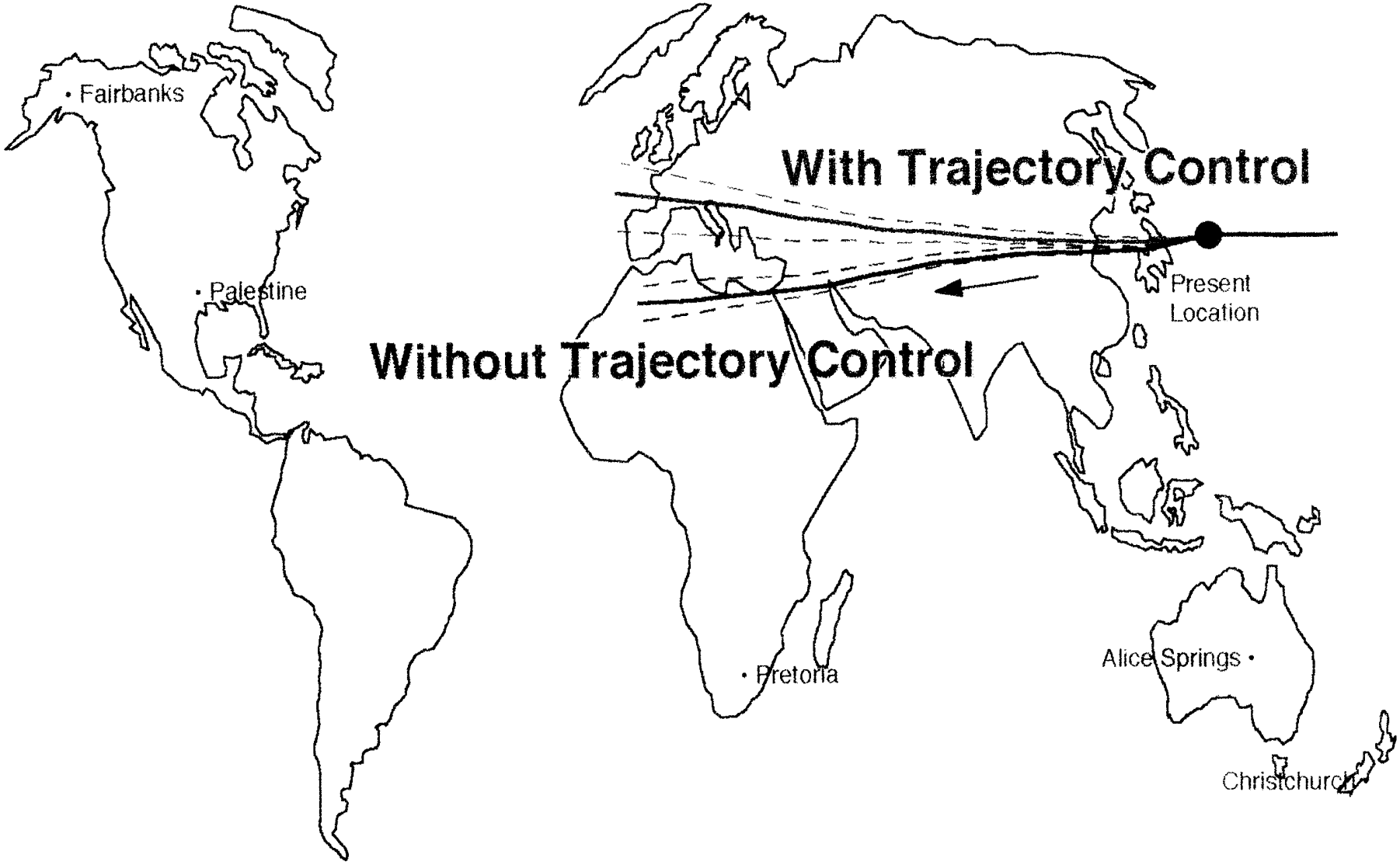


Mission Operations



- **A Trajectory Simulation Tool Will Assist Real-time Mission Sequence Decisions**

Value of Real-time Trajectory Simulation in Mission Operations



Benefits of Mission Planning and Trajectory Simulation

- Program Planning
  - Determine Infrastructure Needs
  - Define Balloncraft System Requirements
  - Evaluate Need for International Agreements
- Mission Planning
  - Assist Mission Launch Site Selection
  - Evaluate coupling of Trajectory with Science Opportunities
  - Evaluate Trajectory Control Necessity
- Mission Operations
  - Look-ahead Capability for Flight Termination
  - Look-ahead Capability for Trajectory Control
  - Integrated Operations Environment

Benefits of Integrated Mission Planning and Trajectory Simulation

- Establishes Necessary Interfaces and Provides Efficient Implementation of Interfaces Among
  - Mission Planning
  - Trajectory Modeling
  - Weather Knowledge
- Weather Information Readily Available to Program and Mission Planners
  - Management of Diverse Weather-related Resources
  - Provide Coherent Summaries of Weather Information
- Multi-purpose Tools
  - Cost-effective and Rapid "What-if" Analyses for All Phases and Elements of ULDB Program
  - Can Be Used in Existing Balloon Program

Capabilities and Experience of Global Aerospace Corporation

- Long-duration Stratospheric Balloon Trajectory Modeling
- Active Balloon Flight Control
- Mission Planning
- Lightweight Power Systems Design and Evaluation
- Integrated Data and Communications Systems
- > 200 Years Combined Aerospace Experience