Mission Automation for "A Train" Correlative Measurements

EOS Dynamic Replanning Using the Earth Phenomena Observing System

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Outline

- **Overview**
- **EPOS system architecture**
- **Concept of operations**
- **AFWA SCFM cloud forecasts**
- **Targets**
- **Planning**
  - Snapshot sensors
  - Modal sensors
  - EO-1
- **Visualization**

Overview – Previous AIST Efforts

- **Developed technologies for an automated mission manager that:**
  - Efficiently utilizes a complementary and cooperative suite of heterogeneous Earth-observing space-based pointable and taskable sensor platforms
  - Responds to significant events, providing enhanced understanding of ephemeral Earth phenomena that impact human life and property, e.g., hurricanes, volcanoes, biomass burning (e.g., forest fires)
  - Provides for long-term data gathering
- **Developed EPOS (Earth Phenomena Observing System) v1.0 – v4.0**
  - Moved from TRL 1/2 to TRL 3
    - **EPOS 1.0**
      - **Optimized dynamic replanning with potentially maneuvering satellites, few targets**
    - **EPOS 2.0**
      - **Optimized dynamic replanning with many coasting satellites/sensors (tested with up to 105), many targets, multiple targets (tested with up to 1450)**
    - **EPOS 3.0**
      - **Modeled existing EOS satellites (and satellites to be launched in the near future)**
      - **MODIS Cloud Mask data used as input**
  - Moved to TRL 4
    - **EPOS 4.0**
      - **Capability to use operational AFWA cloud coverage forecasts as input**
      - **Modeled Aura sensors: TES, HIRDLS**

Overview – Current AIST Effort

- **Objective**
  - Increase the value of data gathered by Earth observing satellites

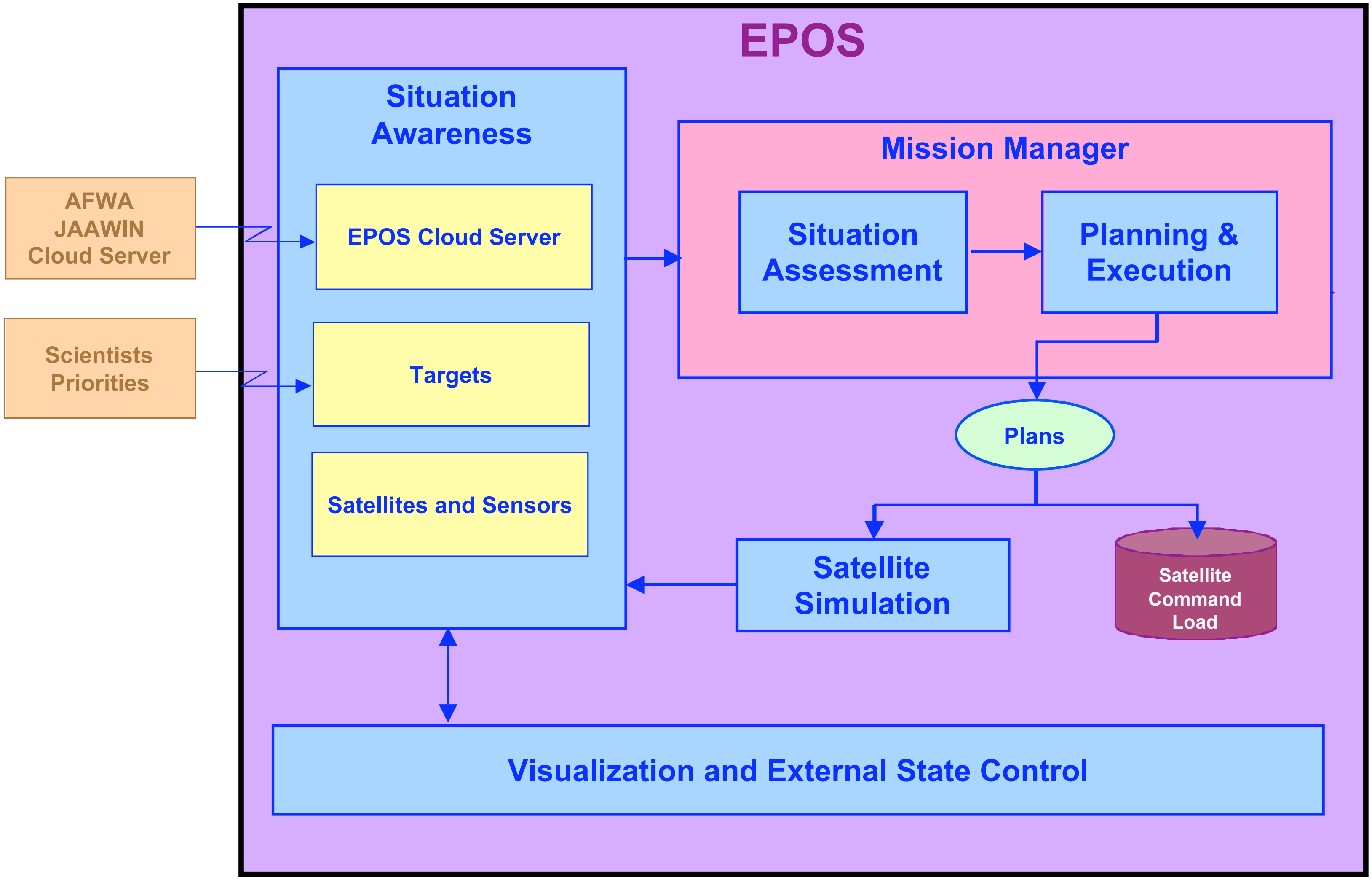
- **Approach**
  - Develop concepts of operation
  - Extend and enhance EPOS to support EO-1 operations
    - **Situation awareness/assessment**
      - **Cloud coverage forecasts**
      - **Target lists and priorities**
    - **Planning and execution**
      - **Near real-time target selection**

  - Development, implementation and integration of other EOS sensor models for TRL 3-4 testing

EPOS for EO-1 Status

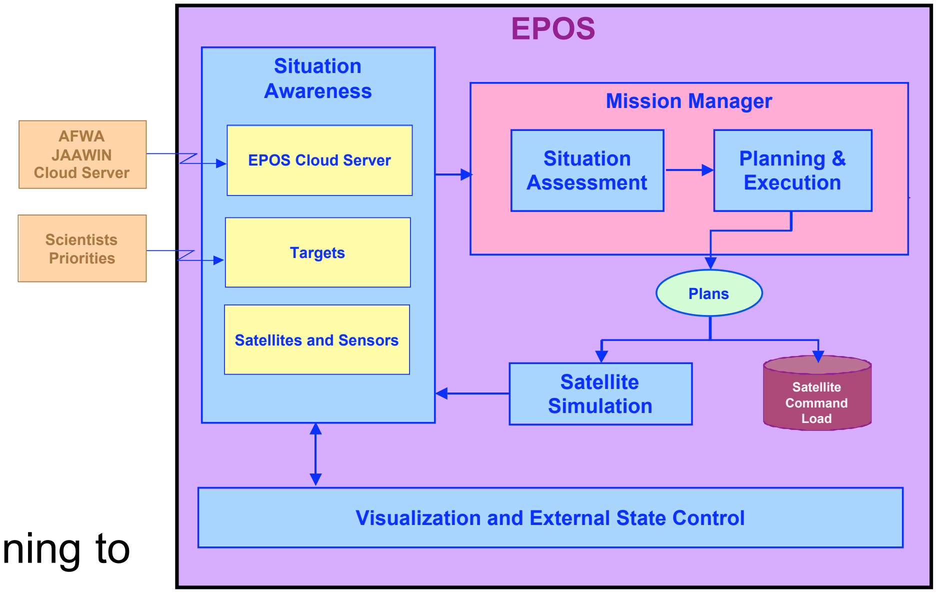
- **Currently EO-1 operations are moving toward being more and more automated**
- **We are in the process of integrating and automating the portion of EPOS functionality used for supporting EO-1 operations**
- **Currently performing initial testing**
- **Autonomous 24/7 use of EPOS in support of EO-1 operations by this fall**

EPOS System Architecture



Concept of Operations
Single Sensor Dynamic Tasking – EO-1 Hyperion

- **Inputs**
  - AFWA forecasts of cloud coverage
  - Prioritized imaging requests for scenes
- **Situation Awareness**
  - Cloud cover forecast
  - Target list and priorities
  - Satellite/sensor models
- **Situation Assessment**
  - Provides data to event-based replanning to improve the likelihood of getting a cloud-free image
- **Planning & Execution**
  - Optimization-based planning to maximize total value gained from observations, e.g., cloud-free scenes
  - Execution is performed by creating appropriate command loads with sufficient lead time for uploading
- **Visualization**
  - Allows the user to examine potential image sites along with either current or forecast cloud cover



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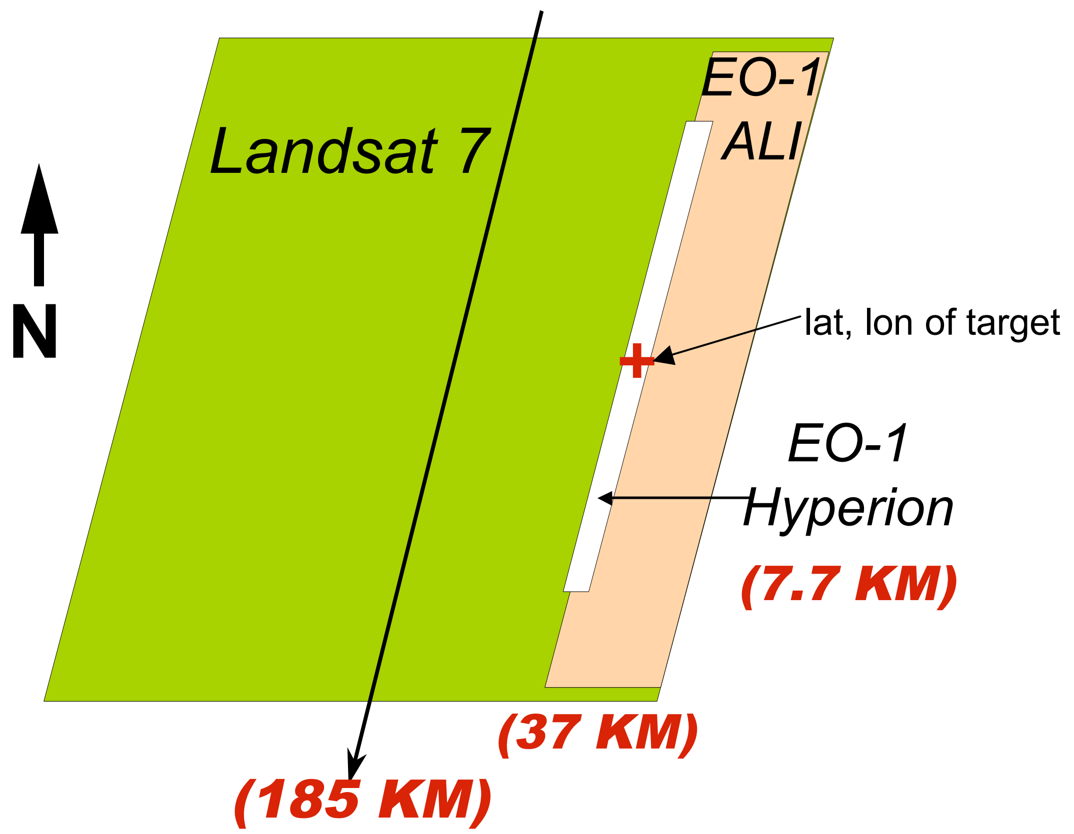
EO-1 Imaging

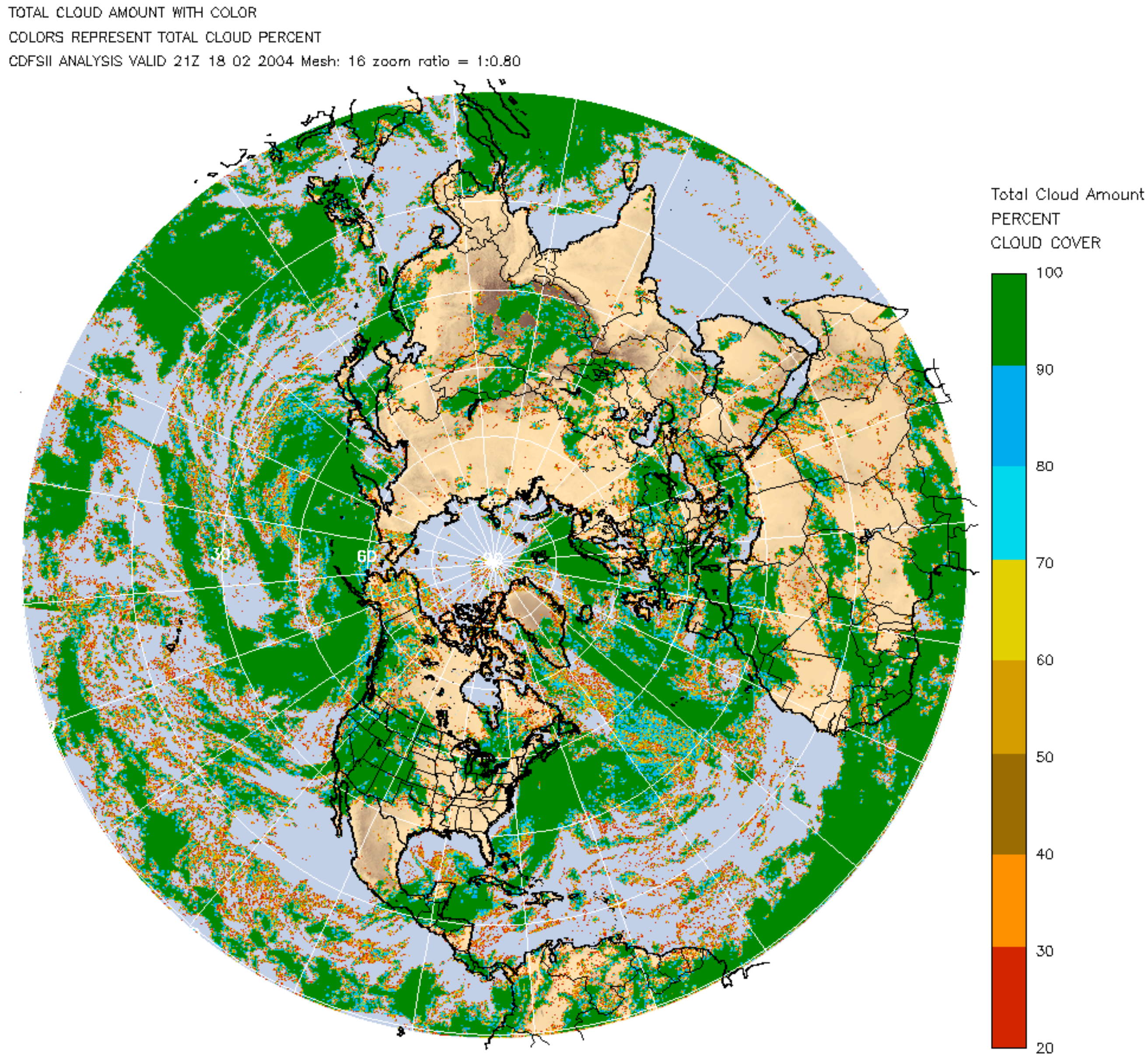
- **Hyperion on EO-1 is a high resolution hyperspectral imager**
- **Has capabilities for off-nadir pointing**
  - For off-nadir pointing, EO-1 is slewed
- **EO-1 and Landsat 7 Descending Orbit Ground Tracks**



Cloud Cover Data

- **Data from AFWA's Stochastic Cloud Forecast Model is used for cloud cover forecasting and decision-making in EPOS**
- **The model uses observed cloud data from five geosynchronous and four polar orbiting satellites**
- **AFWA's cloud forecast system provides hemispheric polar-stereographic grids in Gridded Binary format at six-hour intervals**
  - The data is provided in polar-stereographic grids of 1024 by 1024 for each hemisphere with cells having a rectangular dimension of approximately 24 km at ±60° latitude
  - Cloud forecasts are generated at 00Z, 06Z, 12Z and 18Z; each forecast contains 56 files
    - **One forecast file for each hemisphere for every 3-hour period in an 84 hour forecast duration**
    - **Cloud amounts are expressed in percentages to the nearest 1%,**
    - **The cloud forecast is available on the EPOS Cloud Server approximately 1.5 hours after the generation times**

AFWA Visualized Cloud Data



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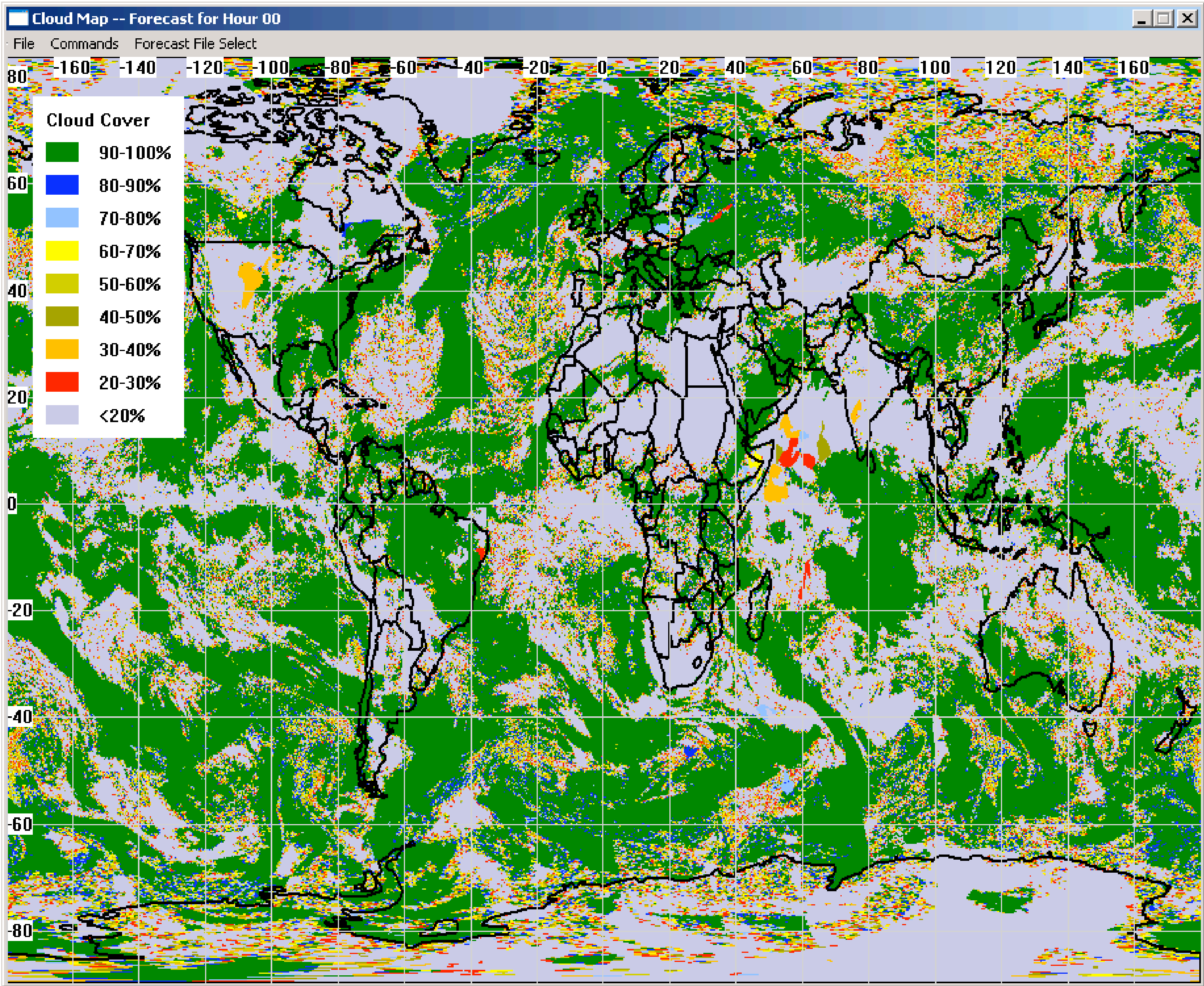
Latitude/Longitude View of Cloud Data



EO-1 Target List

- The target list for EO-1 is provided weekly in the form of a table
- The primary target is marked with a single x, secondary target with xx
- Telemetry, Tracking, and Command (TT&C) messages occur at an SB Pass
- Downloading of the image data and subsequent reinitialization of the onboard data storage occurs at an XB Pass

Primary target

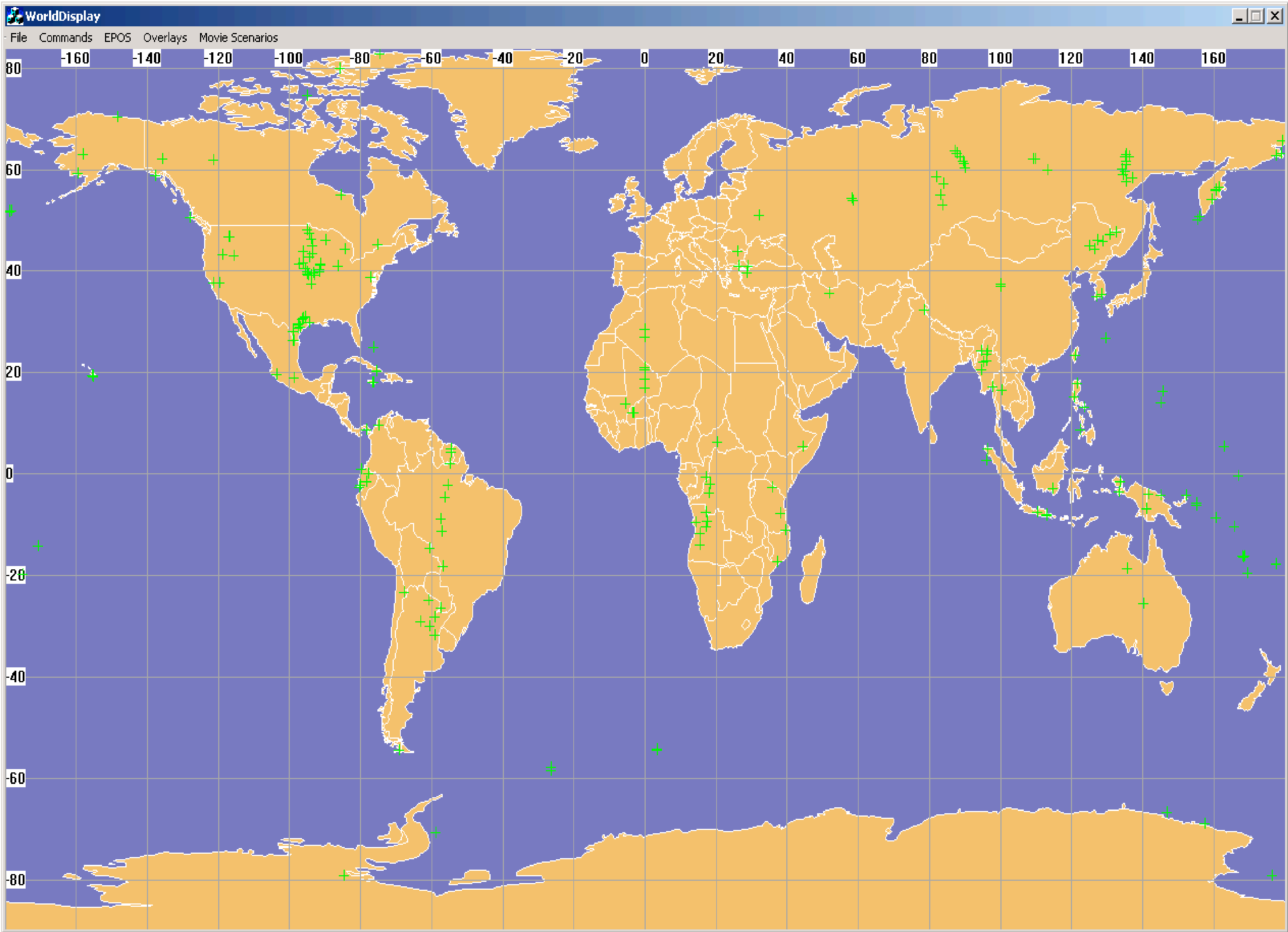
Secondary target

Selected	Special Request	Op Type	Start Time	Stop Time	Duration	Site Latitude	Site Longitude
		Light	165:21:05:17		1:04:54		
	Tunu N Night [EDC/E2] 9793 JPL	PRI DCE	165:21:18:43	165:21:18:56	0:00:13	78.0167	-34
	Petermann G1 Night [EDC/E2] 9794 JPL	PRI DCE	165:21:19:58	165:21:20:09	0:00:11	80.75	-54
	Ward Hunt Ice Shelf Night [EDC/E2] 9449 JP	PRI DCE	165:21:20:10	165:21:20:33	0:00:23	82.75	-74.5833
	Prudhoe Bay [EDC/E] 7594 JPL	PRI DCE	165:21:26:06	165:21:26:15	0:00:09	70.336	-148.362
	New Stuyahok [EDC/N] 4735f	PRI DCE	165:21:29:15	165:21:29:23	0:00:08	59.45167	-157.308
x	Dillingham [EDC/N] 3365f	PRI DCE	165:21:29:24	165:21:29:33	0:00:09	59.04	-158.456
	Ilnik [EDC/N] 4074f	PRI DCE	165:21:30:06	165:21:30:13	0:00:07	56.59694	-159.626
	Mastuevich Glacier [EDC/N] 8157 JPL	PRI DCE	165:22:05:11	165:22:05:19	0:00:08	-68.9968	157.4081
		Eclipse	165:22:10:21		0:33:38		
		Light	165:22:44:10		1:04:54		
x	TT&C	SB Pass	165:22:51:01	165:23:03:06	0:12:05		
xx	Data download	XB Pass	165:22:51:01	165:23:03:06	0:12:05		
x		XB Pass	165:22:51:01	165:23:02:48	0:11:47		
	KAR Night [EDC/W2] 9738 JPL	PRI DCE	165:22:54:41	165:22:54:54	0:00:13	69.7	-33
	Summit Night [EDC/W] 9624 JPL	PRI DCE	165:22:55:38	165:22:55:47	0:00:09	72.5833	-38.5
	NGRIP Night [EDC/W2] 9739 JPL	PRI DCE	165:22:56:21	165:22:56:34	0:00:13	75.1	-42.333
	Humboldt Night [EDC/W] 9625 JPL	PRI DCE	165:22:57:40	165:22:57:49	0:00:09	78.5333	-56.833
xx	T089024 [EDC/N] 7257f	PRI DCE	165:23:10:09	165:23:10:17	0:00:08	52.4317	173.6225
	Bagana [EDC/E2] 9297 JPL	PRI DCE	165:23:26:29	165:23:26:42	0:00:13	-6.143	155.194
	Posarae [EDC/N] 6713f	PRI DCE	165:23:26:45	165:23:26:53	0:00:08	-7.3408	157.2567
x	Mbiula [EDC/N] 6714f	PRI DCE	165:23:27:00	165:23:27:08	0:00:08	-8.2581	157.4253
	Tetemara [EDC/N] 6715f	PRI DCE	165:23:27:03	165:23:27:11	0:00:08	-8.4983	157.7242
		Eclipse	165:23:49:14		0:33:38		
		Light	166:00:23:03		1:04:53		

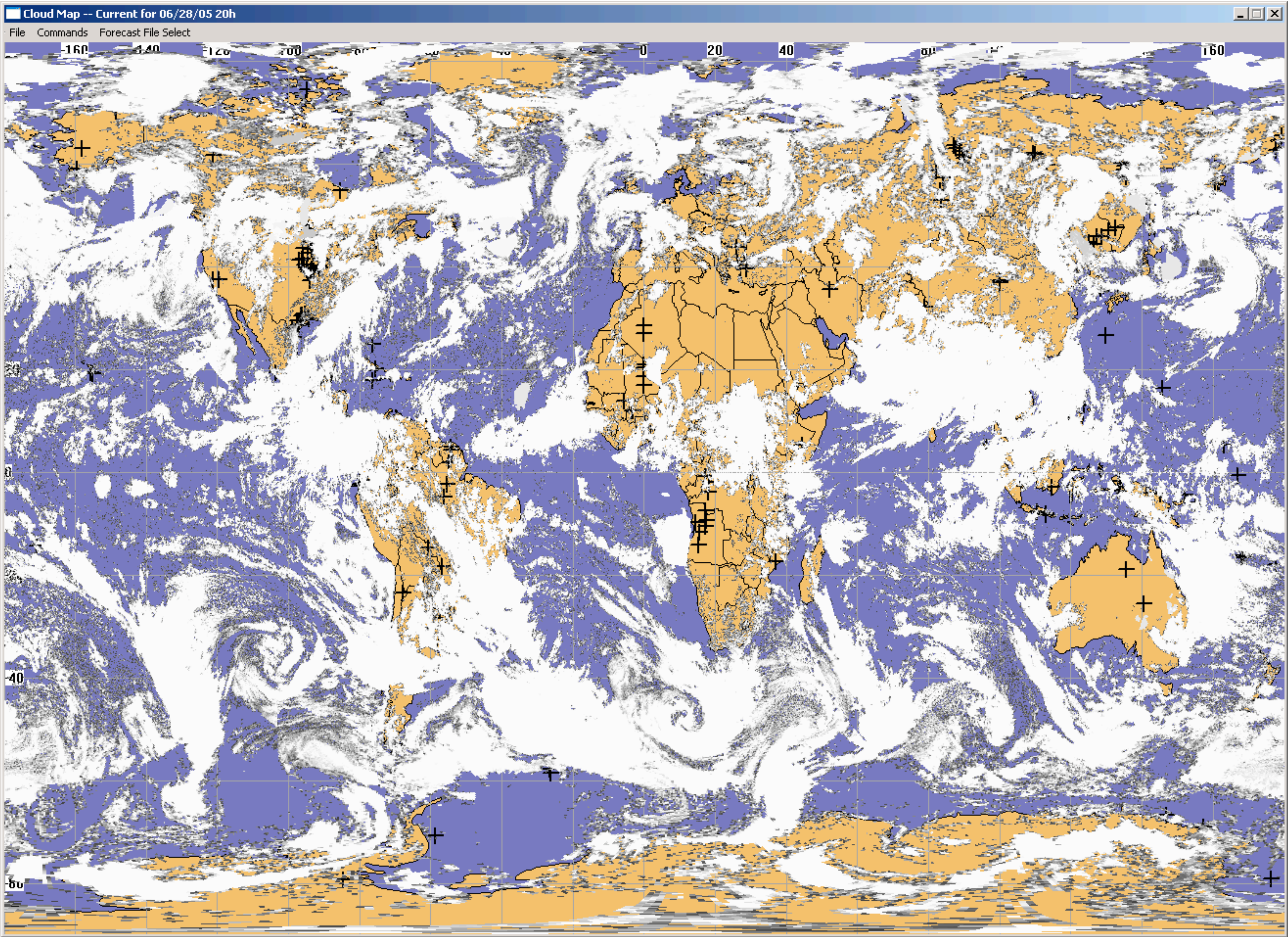
EO-1 Target Priorities

Priority	Description
100 (highest)	Anomaly Investigation
200	Security
300	Emergency Response
400	EO-1 Sensor Calibrations and Maintenance
500	Priority Tasked with Coordinated Ground Truth
600	Priority Paid
625	JPL Priority
650	Paid
675	JPL & Bulk Customer
700	Sensorweb Priority
750	Sensorweb and Speculatively Tasked Emergency Response
800	Priority Speculative USGS or NASA Science
850	Speculative USGS or NASA Science
900 (lowest)	USGS Speculative

Targets


WorldDisplay
File Commands EPOS Overlays Movie Scenarios
-160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160
80 60 40 20 0 -20 -40 -60 -80

Targets and Clouds



Cloud Forecasts will Improve Value

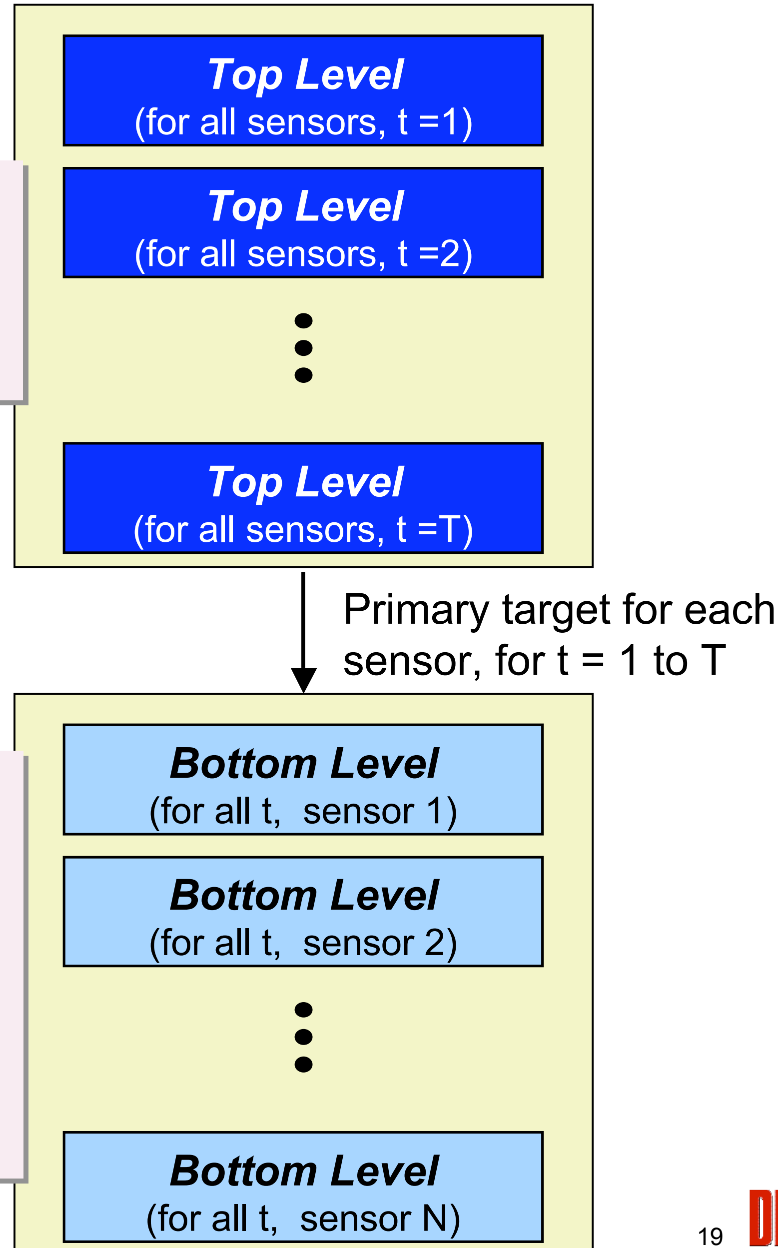
		Actual	
		Not Cloudy	Cloudy
Forecast	Not Cloudy	**19.3%**	**9.9%**
	Cloudy	**21.4%**	**49.4%**

- **~200 targets from June 2 – 26, 2005**
- **Forecast lead time of six hours**
- **In this case, using a forecast results in 66.2% of the images that are not cloud covered**
- **Operating without considering cloud forecasts results in 40.7% of images that are not cloud covered**

Optimization-Based Observation Planning Approaches

"Snapshot" Sensors: Plan Optimization

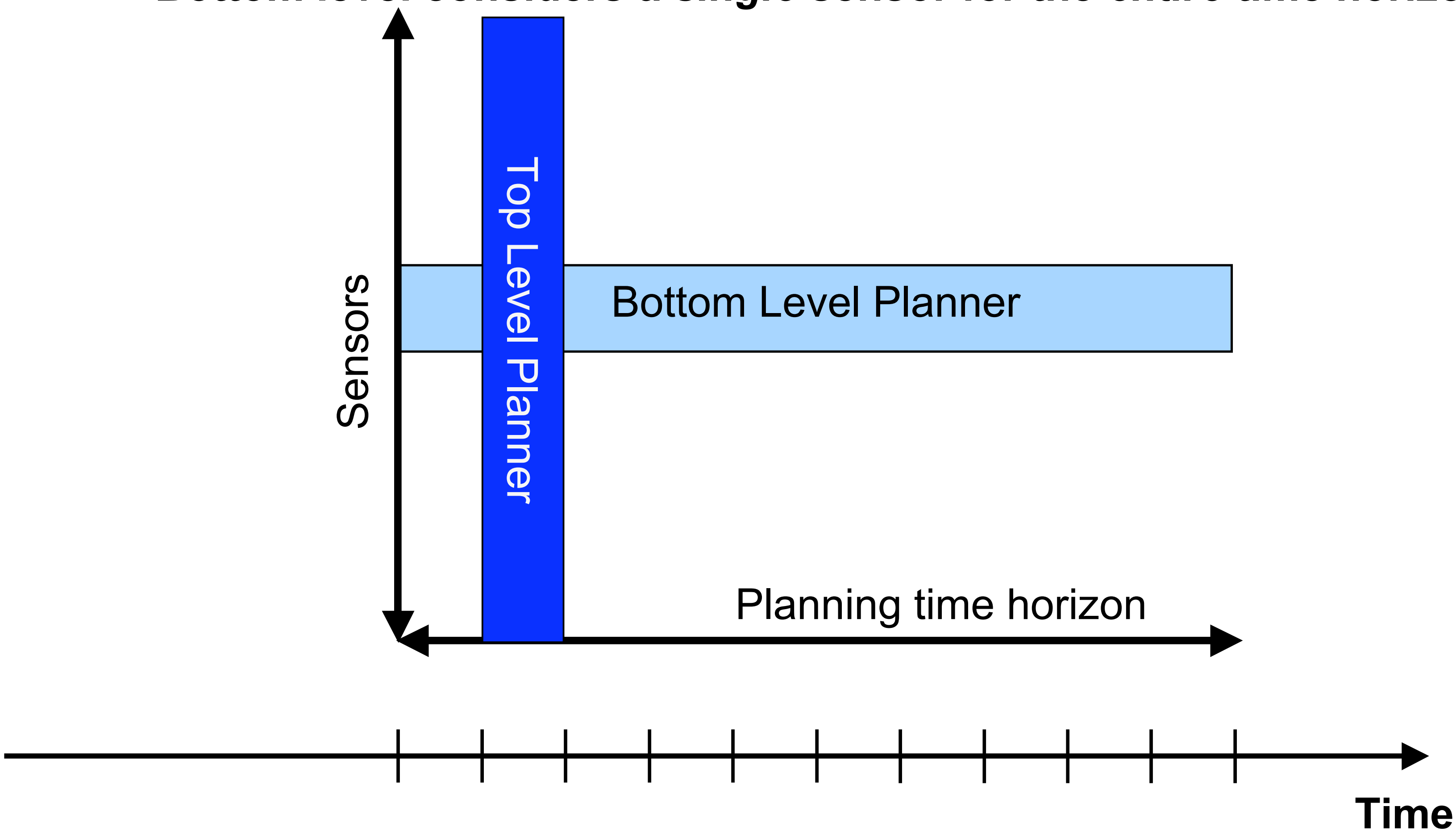
- Maximize total science utility from all sensors for each time period *t* in the planning horizon T
- Identify *primary* target for each sensor



- Refine top level plan
- Maximize total science utility for each sensor over the planning horizon
  - Considers primary, secondary and long-term targets
- Generate pointing commands for each sensor

“Snapshot” Sensors: Decomposition

- **Top level considers *all* sensors and targets for a *single* time period**
- **Bottom level considers a *single* sensor for the *entire* time horizon**



Modal Sensor Planning: General Problem

- **Input data:**
  - A planning interval, a set of modes, an observation value function, and the amount of resources (e.g., data storage) available
- **Decisions:**
  - A sensor tasking plan
- **Objective:**
  - Maximize total observation value
- **Constraints:**
  - Available resources

Modal Sensor Planning: Special Case

- **Mode transition times are chosen from a discrete subset of the planning interval**
- **There is an idle mode whose duration is arbitrarily small**
  - This technical condition makes it easy to schedule the idle mode
- **A mode, if scheduled, runs to completion**
  - The instrument is idle from the time of mode completion until the next available transition time
- **There are no resource constraints**

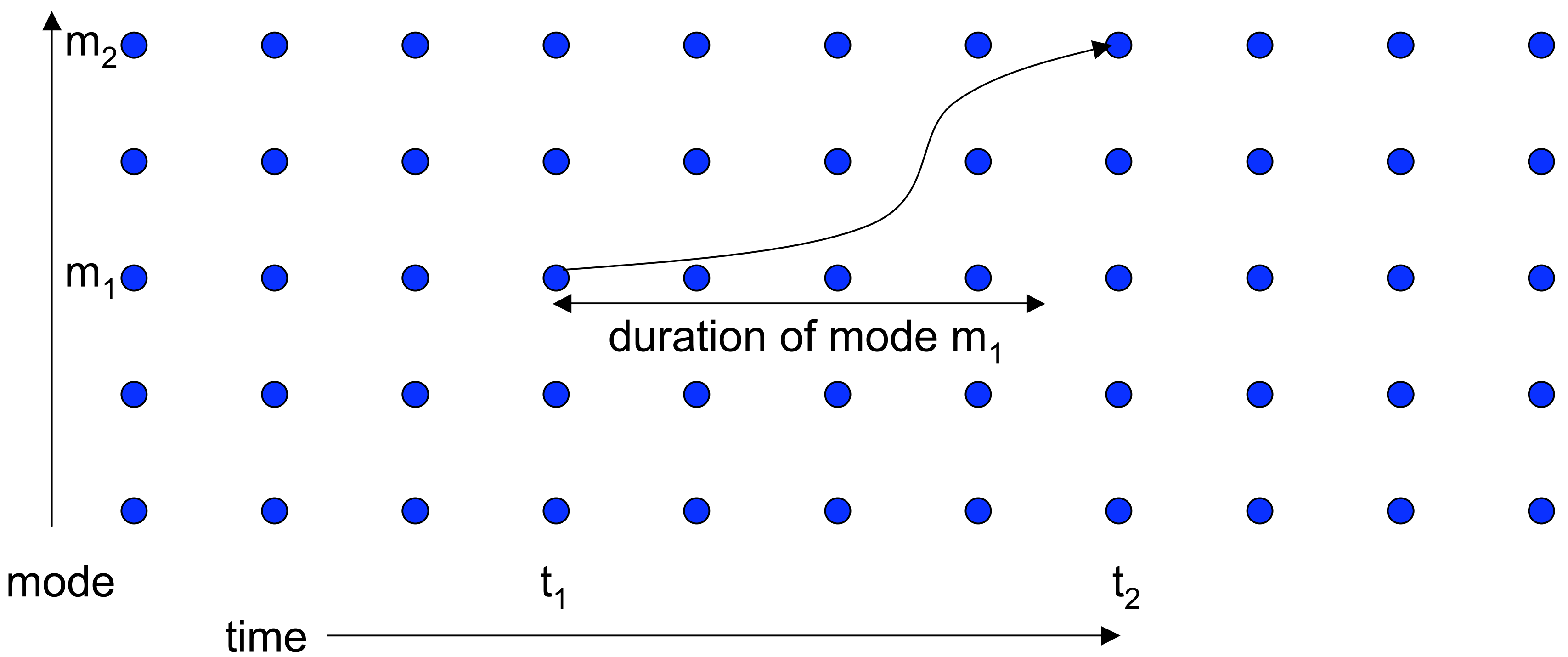
Modal Sensor Plan Optimization

- **A sensor tasking plan is a time-tagged sequence of mode commands (t_1,m_1), (t_2,m_2), …, (t_r,m_r)**
  - Command mode m_1 at time t_1, then command mode m_2 at time , and so forth
- **A mode can correspond to a scan pattern in the sensor pointing angles**
  - E.g., design of HIRDLS Global Observing Mode
- **Modes have a duration = T(m)**
  - E.g., TES Global Survey Mode has a duration of 81.2 seconds

Modal Sensor Planning: Acyclic Graph

Cost on feasible arc leaving mode m at time t_1 = –value of starting mode m_1 at time t_1

Consider only the arcs that go to a node with time greater than the duration of mode m_1



Optimized Plan

- **The optimal plan is found by finding the shortest path in the acyclic graph**
- **A shortest path in a topologically ordered directed acyclic graph with n vertices and e edges and a unique source vertex (a vertex which is smallest in the topological ordering) can be determined in time O(n + e)**
- **For an example with 5 modes (including idle), with durations between 27 and 93 seconds and a planning horizon of 90 minutes (5400 seconds)**
  - 27,005 nodes
  - ~135,000 edges
  - 47 milliseconds for the optimal path (3.2 GHz Pentium 4 / Windows XP)

EO-1 Scene Planning

(Simulation only)

Planning using Dynamic Programming (1)

- **Inputs**
  - Target location (lat, lon)
  - Imaging start and end times
- **Constraints**
  - Resource availability (e.g., storage)
  - Slew rate bounds
- **Intermediate calculations**
  - Initial pointing angles
  - Final pointing angles
- **Target i represented by (t_i, x_i , y_i , t_i' , x_i' , y_i' , r_i , v_i)**
  - t_i is time at which imaging of i would commence, t_i' is time at which imaging of i would end, x_i and y_i are initial pointing angles, x_i' and y_i' are final pointing angles, r_i is resource needed (e.g., data storage), and v_i is value

Planning using Dynamic Programming (2)

Choose a target subsequence S of largest total value, subject to a resource constraint:

$$\sum_{i \in S} r_i \le R$$

and to slewing constraints: If i and j are consecutive elements of S, we require that

$$| x_j - x_i' | \le (t_j - t_i' - \sigma) s_x$$

$$| y_j - y_i' | \le (t_j - t_i' - \sigma) s_y$$

Constants s_x and s_y are slew rate bounds; σ is a constant called settling time.

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Planning using Dynamic Programming (3)

- **Let q denote system state**
  - q is a 4-tuple (t, x, y, r) where x and y are pointing angles which occur at time t, and r is resource available.
- **Target i = (t_i, x_i, y_i, t_i', x_i', y_i', r_i, v_i) is *feasible* from q = (t, x, y, r), and write i | q if the following four conditions hold:**

$$t_i \le t \qquad r_i \le r \qquad |x_i - x| \le (t_i - t - \sigma)s_x \qquad |y_i - y| \le (t_i - t - \sigma)s_y$$

- **Each state q has value V(q), the largest total value we can obtain by scheduling targets if the initial state is q**
  - The principle of optimality allows value to be determined recursively

$$V(q) = \max_{i|q} (v_i + V(q^i))$$

- **where the state q_i is defined as follows:**

$$q^i = (t_i', x_i', y_i', r - r_i)$$

- **The *first* target in an optimal schedule is the i for which V(q) is maximized – subsequent targets are found in the recursion**

Planning using Dynamic Programming (3)

- **Let q denote system state**
  - q is a 4-tuple (t, x, y, r) where x and y are pointing angles which occur at time t, and r is resource available.
- **Target i = (t_i , x_i , y_i , t_i' , x_i' , y_i' , r_i , v_i) is *feasible* from q = (t, x, y, r), and write i | q if the following four conditions hold:**

$$t_i \le t \qquad r_i \le r \qquad |x_i - x| \le (t_i - t - \sigma)s_x \qquad |y_i - y| \le (t_i - t - \sigma)s_y$$

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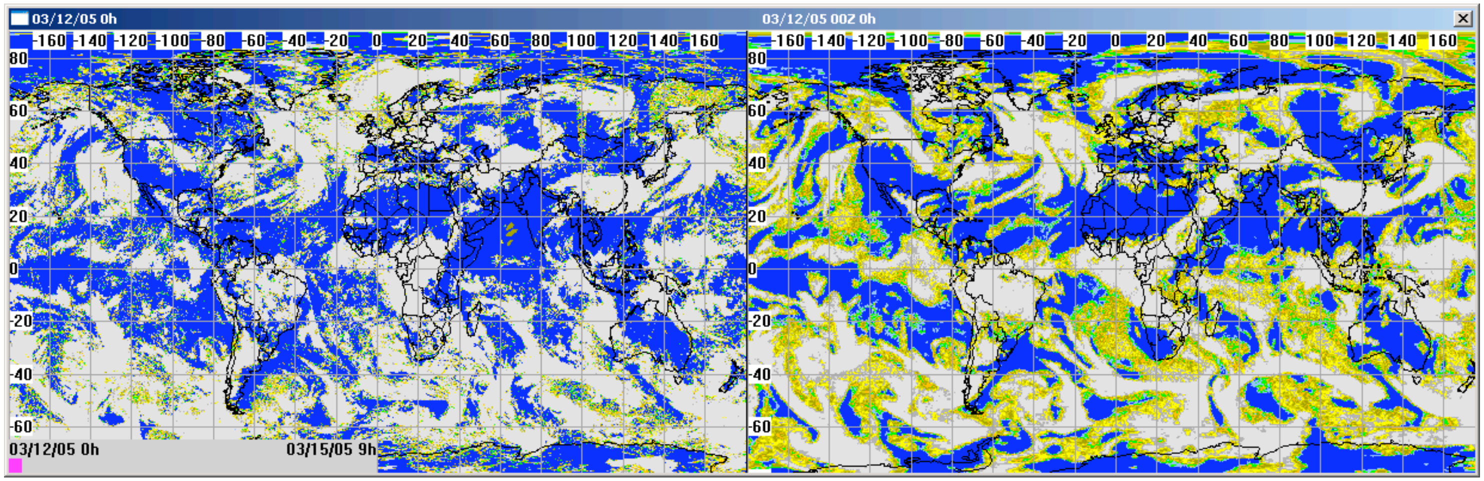
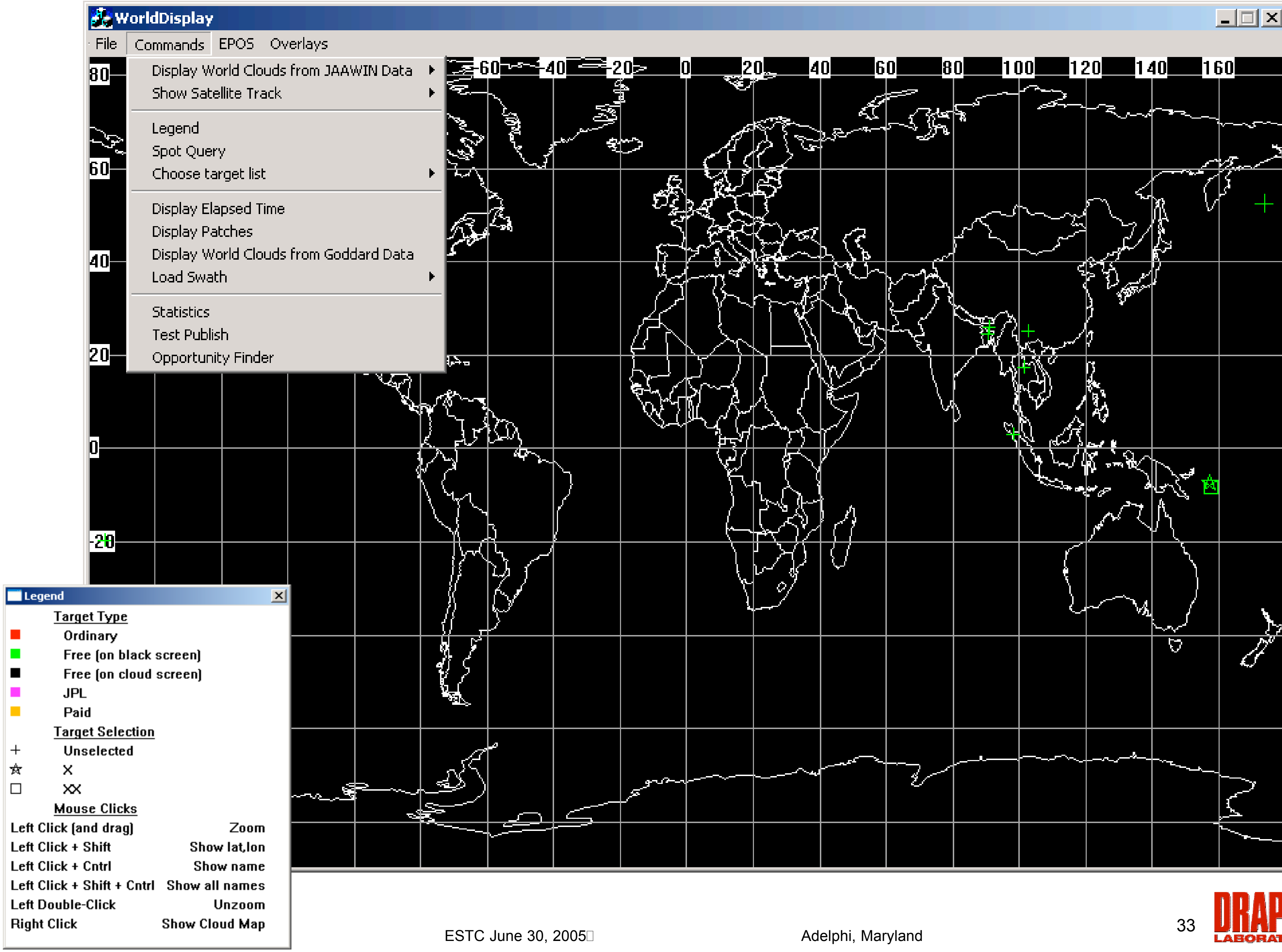
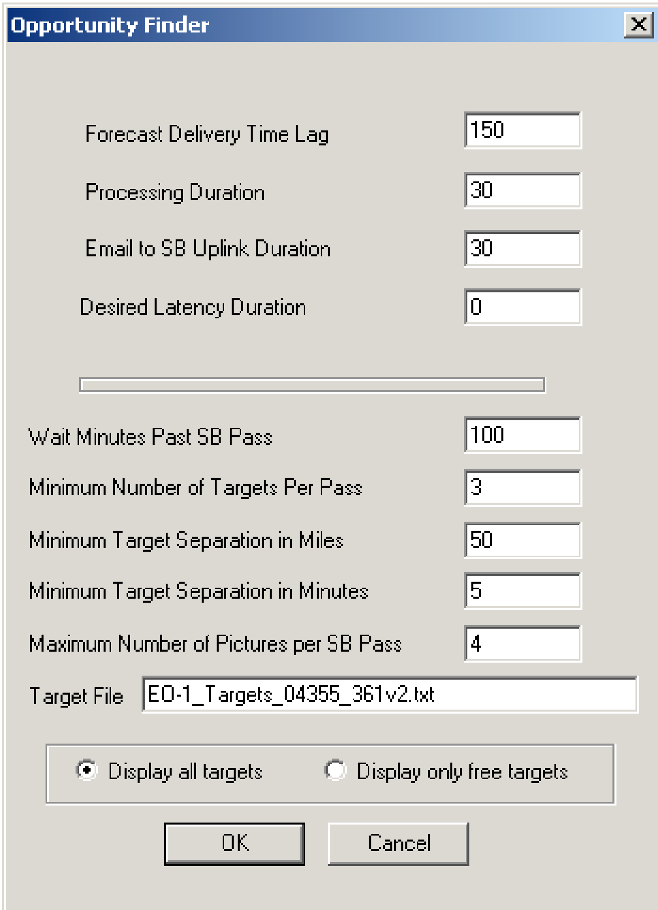
Visualization

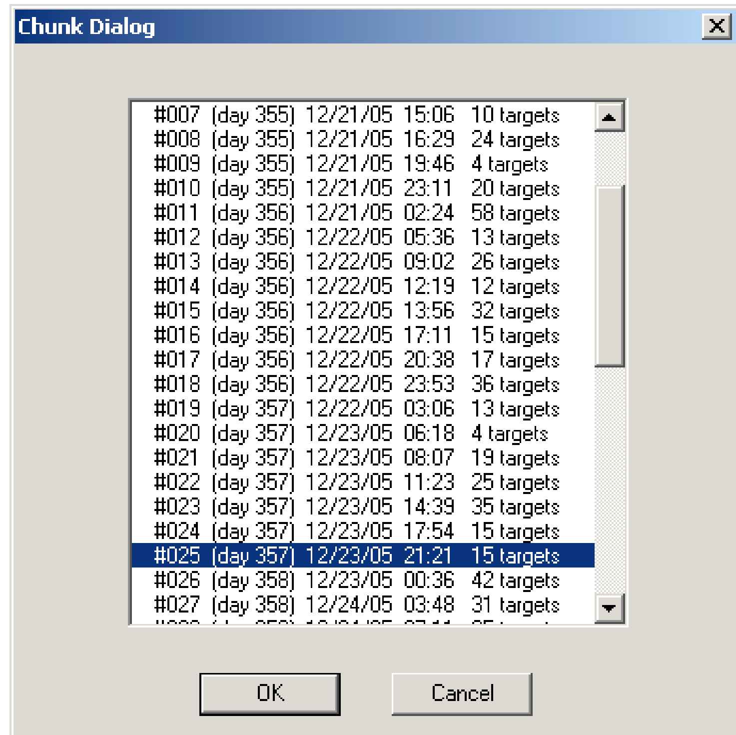
Visualization

- **The EPOS WorldDisplay presents a Mercator projection of the Earth**
  - It includes administrative boundaries, rivers, targets, satellite ground tracks, and cloud cover
  - It can show the EO-1 swath of potential views, i.e., an optional display of 2.5 WRS swath on either side of the nadir track of EO-1
  - It can be used to generate single images or a series of images as a movie.
- **The first frame of an example side-by-side movie is shown**

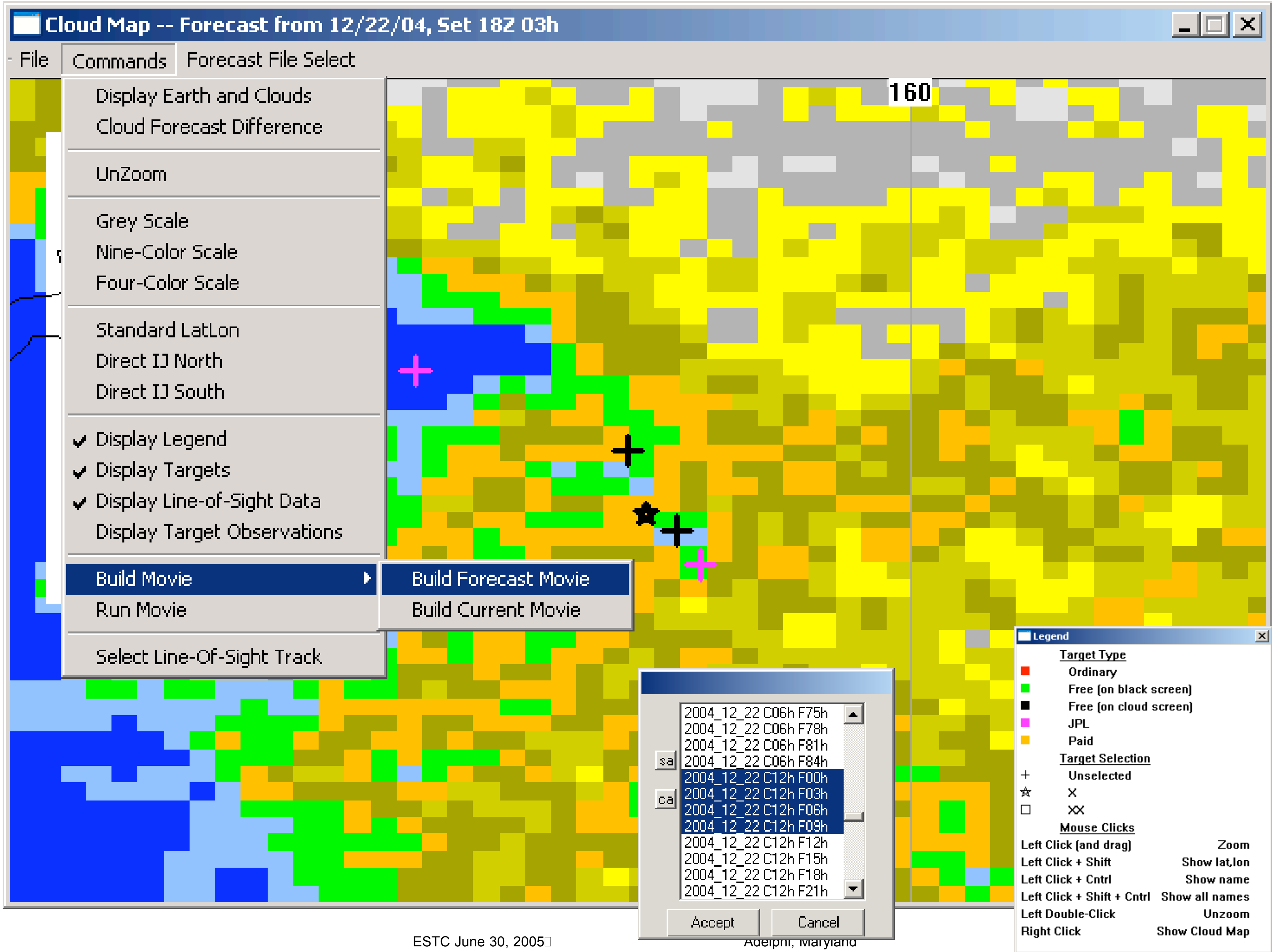


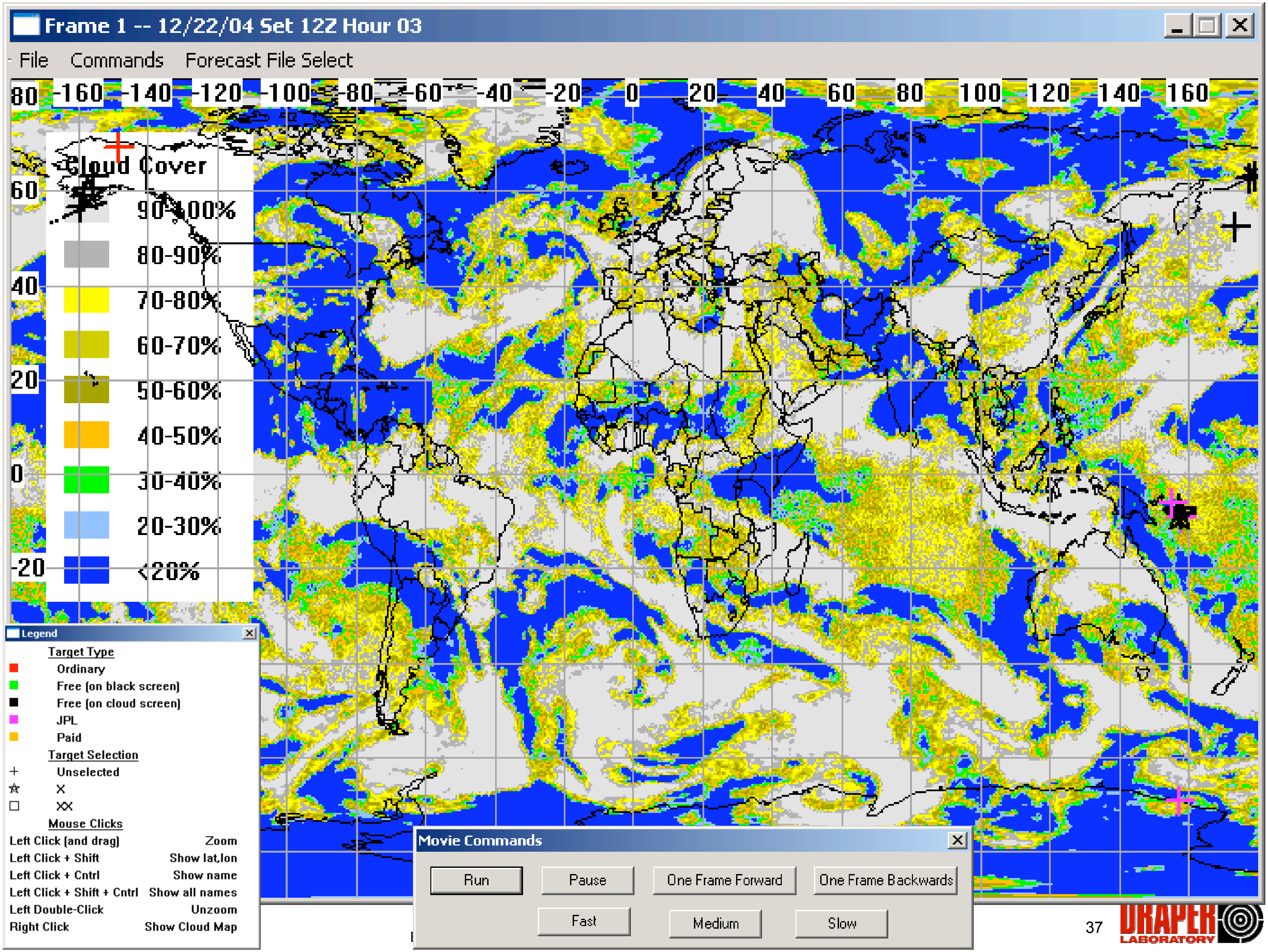

WorldDisplay
File
Commands
EPOS
Overlays
Display World Clouds from JAAWIN Data
Show Satellite Track
Legend
Spot Query
Choose target list
Display Elapsed Time
Display Patches
Display World Clouds from Goddard Data
Load Swath
Statistics
Test Publish
Opportunity Finder
Legend
Target Type
Ordinary
Free (on black screen)
Free (on cloud screen)
JPL
Paid
Target Selection
Unselected
X
XX
Mouse Clicks
Left Click (and drag) Zoom
Left Click + Shift Show lat,lon
Left Click + Cntrl Show name
Left Click + Shift + Cntrl Show all names
Left Double-Click Unzoom
Right Click Show Cloud Map

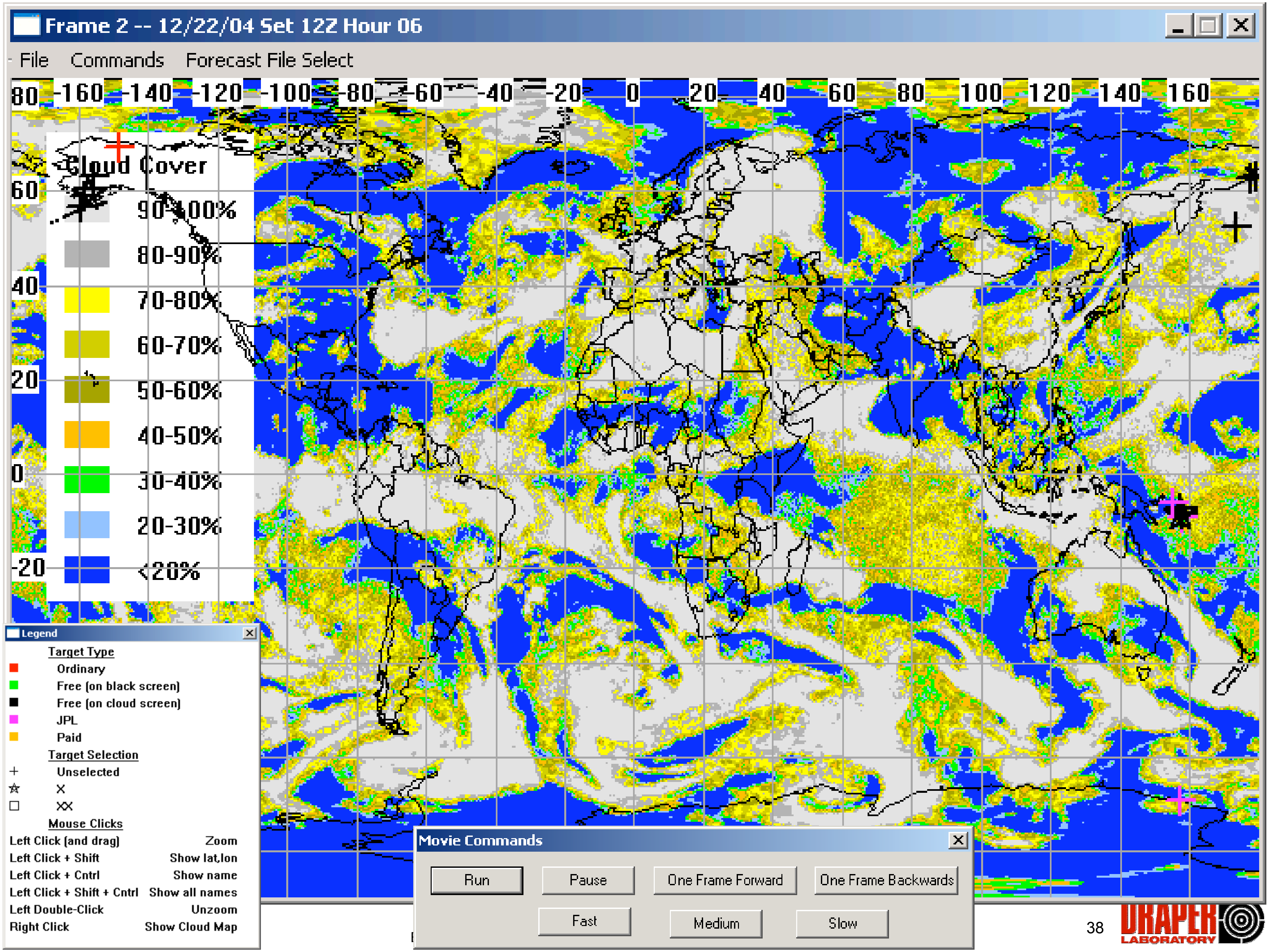

Opportunity Finder
Forecast Delivery Time Lag 150
Processing Duration 30
Email to SB Uplink Duration 30
Desired Latency Duration 0
Wait Minutes Past SB Pass 100
Minimum Number of Targets Per Pass 3
Minimum Target Separation in Miles 50
Minimum Target Separation in Minutes 5
Maximum Number of Pictures per SB Pass 4
Target File EO-1_Targets_04355_361v2.txt
Display all targets
Display only free targets
OK
Cancel


Chunk Dialog
#007 (day 355) 12/21/05 15:06 10 targets
#008 (day 355) 12/21/05 16:29 24 targets
#009 (day 355) 12/21/05 19:46 4 targets
#010 (day 355) 12/21/05 23:11 20 targets
#011 (day 356) 12/21/05 02:24 58 targets
#012 (day 356) 12/22/05 05:36 13 targets
#013 (day 356) 12/22/05 09:02 26 targets
#014 (day 356) 12/22/05 12:19 12 targets
#015 (day 356) 12/22/05 13:56 32 targets
#016 (day 356) 12/22/05 17:11 15 targets
#017 (day 356) 12/22/05 20:38 17 targets
#018 (day 356) 12/22/05 23:53 36 targets
#019 (day 357) 12/22/05 03:06 13 targets
#020 (day 357) 12/23/05 06:18 4 targets
#021 (day 357) 12/23/05 08:07 19 targets
#022 (day 357) 12/23/05 11:23 25 targets
#023 (day 357) 12/23/05 14:39 35 targets
#024 (day 357) 12/23/05 17:54 15 targets
#025 (day 357) 12/23/05 21:21 15 targets
#026 (day 358) 12/23/05 00:36 42 targets
#027 (day 358) 12/24/05 03:48 31 targets
OK
Cancel

0	1	2	3	4	5	6	7	8
x		SB Pass	357:21:21:17	357:21:33:30	0:12:13			
	Sagwon [EDC/N] 10132 USGS	PRI DCE	357:21:26:27	357:21:26:36	0:00:09	69.43278	-148.6728	
	McGrath [EDC/N] 3810f	PRI DCE	357:21:28:23	357:21:28:31	0:00:08	62.9564	-155.5942	
x	New Stuyahok [EDC/N] 4735f	PRI DCE	357:21:29:21	357:21:29:29	0:00:08	59.45167	-157.3078	
	Dillingham [EDC/N] 3365f	PRI DCE	357:21:29:30	357:21:29:39	0:00:09	59.04	-158.4558	
	Ilnik [EDC/N] 4074f	PRI DCE	357:21:30:12	357:21:30:20	0:00:08	56.59694	-159.6256	
	Mastuevich Glacier [EDC/N] 8157 JPL	PRI DCE	357:22:05:19	357:22:05:27	0:00:08	-68.99679	157.4081	
	Alkatvaan [EDC/E] 2540f	PRI DCE	357:23:07:15	357:23:07:23	0:00:08	63.1336	179.0344	
	Valkatvaan [EDC/E] 2406f	PRI DCE	357:23:07:25	357:23:07:33	0:00:08	62.7247	177.665	
	T089024 [EDC/N] 7257f	PRI DCE	357:23:10:16	357:23:10:24	0:00:08	52.4317	173.6225	
	Bagana [EDC/E2] 9297 JPL	PRI DCE	357:23:26:35	357:23:26:48	0:00:13	-6.143	155.194	
	Posarae [EDC/N] 6713f	PRI DCE	357:23:26:51	357:23:26:59	0:00:08	-7.3408	157.2567	
x	Mbiula [EDC/N] 6714f	PRI DCE	357:23:27:06	357:23:27:14	0:00:08	-8.2581	157.4253	
	Tetemara [EDC/N] 6715f	PRI DCE	357:23:27:09	357:23:27:17	0:00:08	-8.4983	157.7242	
	Kavachi [EDC/N] 10794 JPL	PRI DCE	357:23:27:16	357:23:27:25	0:00:09	-9.02	157.95	


Cloud Map -- Forecast from 12/22/04, Set 182 03h
File
Commands
Forecast File Select
Display Earth and Clouds
Cloud Forecast Difference
UnZoom
Grey Scale
Nine-Color Scale
Four-Color Scale
Standard LatLon
Direct IJ North
Direct IJ South
Display Legend
Display Targets
Display Line-of-Sight Data
Display Target Observations
Build Movie
Run Movie
Select Line-Of-Sight Track
Build Forecast Movie
Build Current Movie
160
2004_12_22 C06h F75h
2004_12_22 C06h F78h
2004_12_22 C06h F81h
2004_12_22 C06h F84h
2004_12_22 C12h F00h
2004_12_22 C12h F03h
2004_12_22 C12h F06h
2004_12_22 C12h F09h
2004_12_22 C12h F12h
2004_12_22 C12h F15h
2004_12_22 C12h F18h
2004_12_22 C12h F21h
sa
ca
Accept
Cancel
Legend
Target Type
Ordinary
Free (on black screen)
Free (on cloud screen)
JPL
Paid
Target Selection
Unselected
X
XX
Mouse Clicks
Left Click (and drag) Zoom
Left Click + Shift Show lat,lon
Left Click + Cntrl Show name
Left Click + Shift + Cntrl Show all names
Left Double-Click Unzoom
Right Click Show Cloud Map


Frame 1 -- 12/22/04 Set 12Z Hour 03
File
Commands
Forecast File Select
80
60
40
20
0
-20
-160
-140
-120
-100
-80
-60
-40
-20
0
20
40
60
80
100
120
140
160
Cloud Cover
90-100%
80-90%
70-80%
60-70%
50-60%
40-50%
30-40%
20-30%
<20%
Legend
Target Type
Ordinary
Free (on black screen)
Free (on cloud screen)
JPL
Paid
Target Selection
Unselected
X
XX
Mouse Clicks
Left Click (and drag) Zoom
Left Click + Shift Show lat,lon
Left Click + Cntrl Show name
Left Click + Shift + Cntrl Show all names
Left Double-Click Unzoom
Right Click Show Cloud Map
Movie Commands
Run
Pause
One Frame Forward
One Frame Backwards
Fast
Medium
Slow



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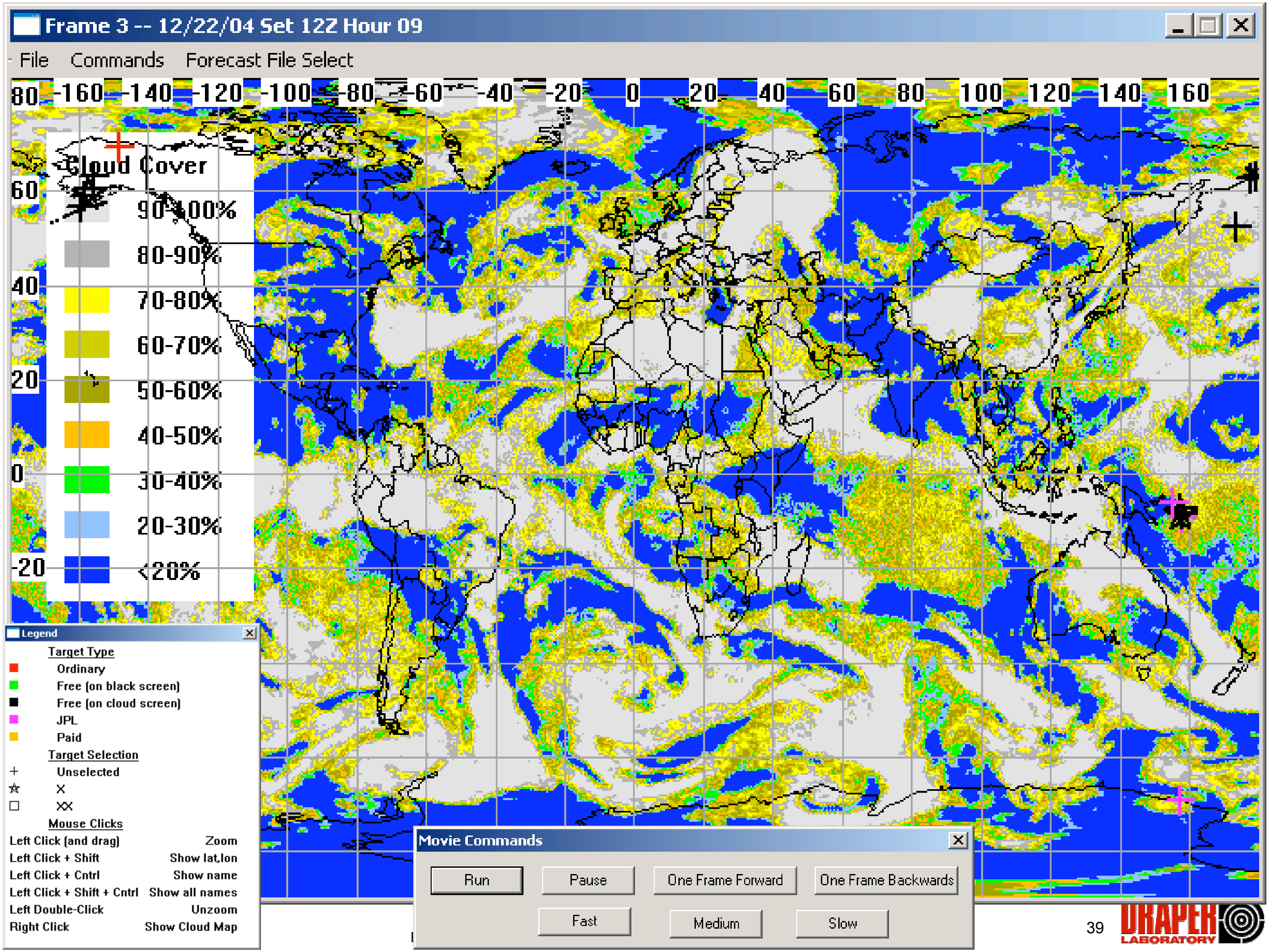
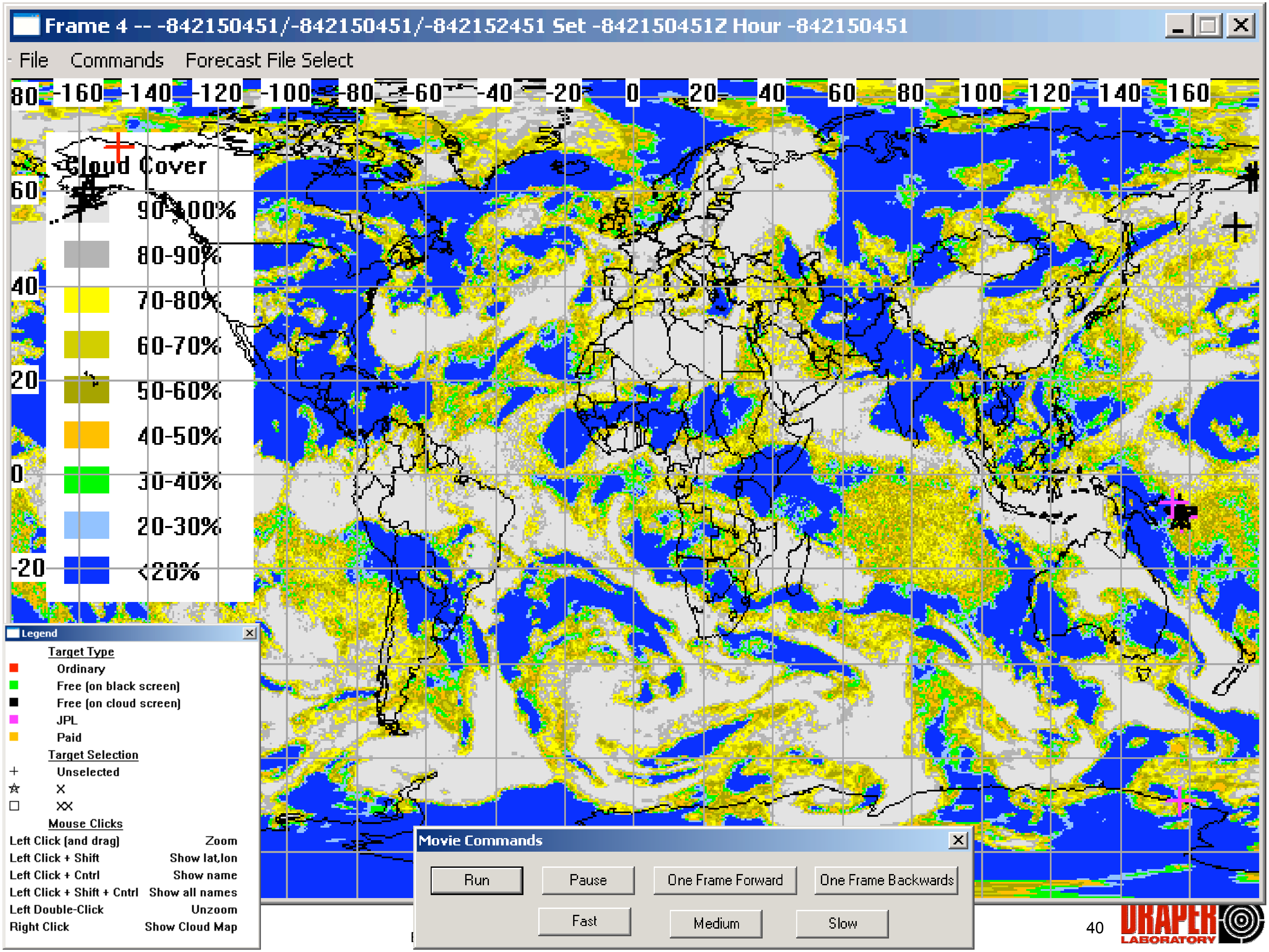
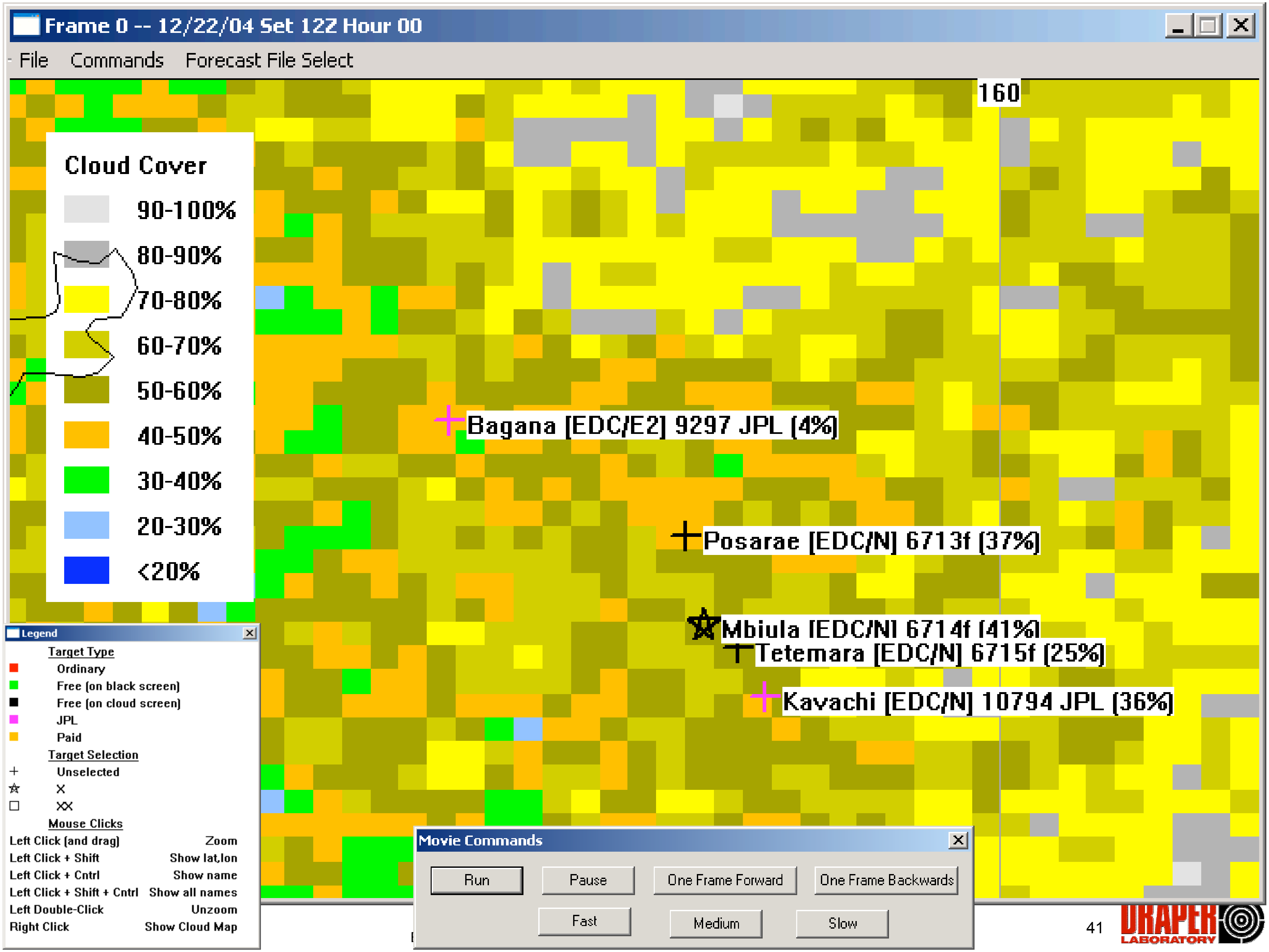
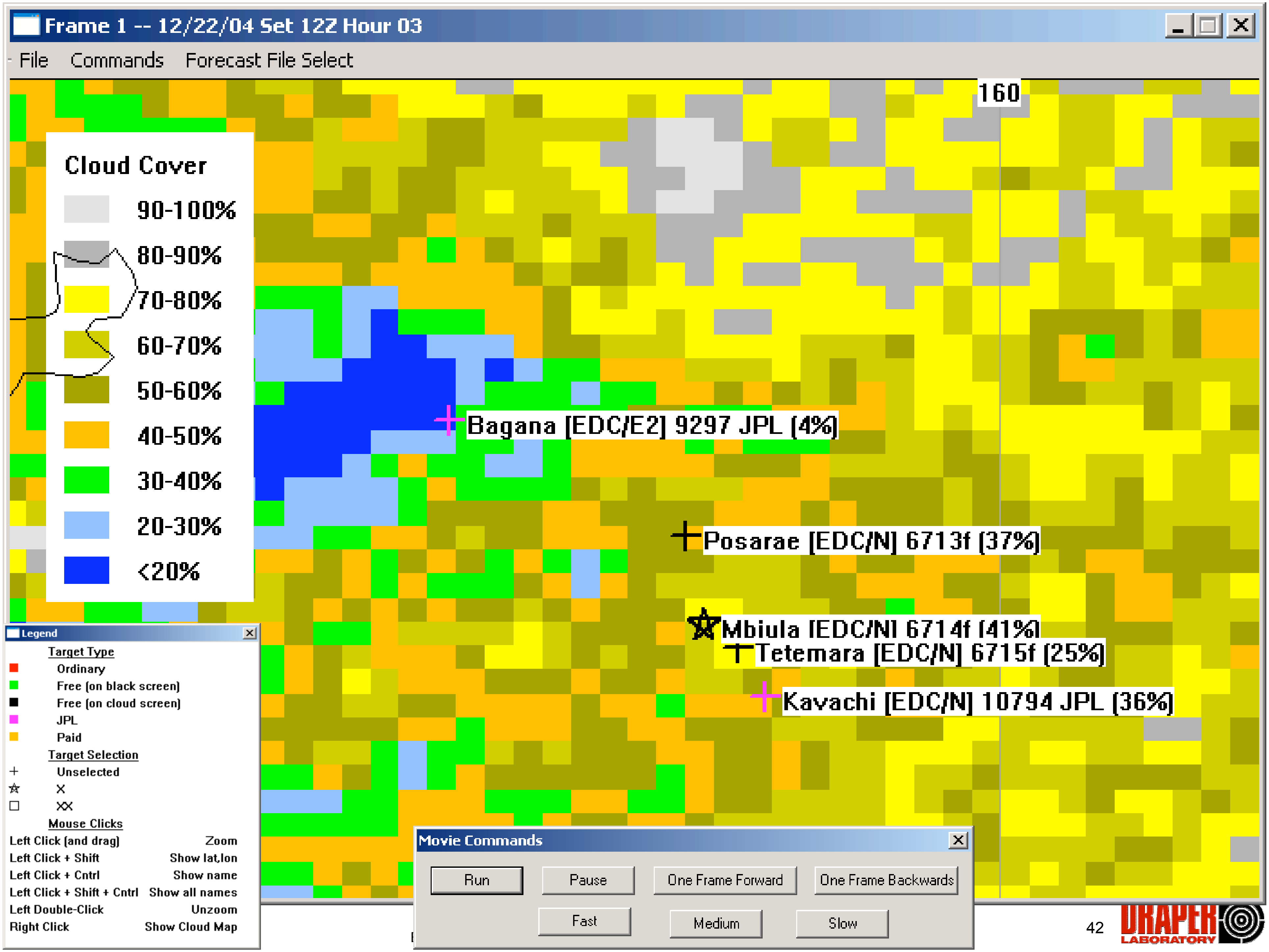


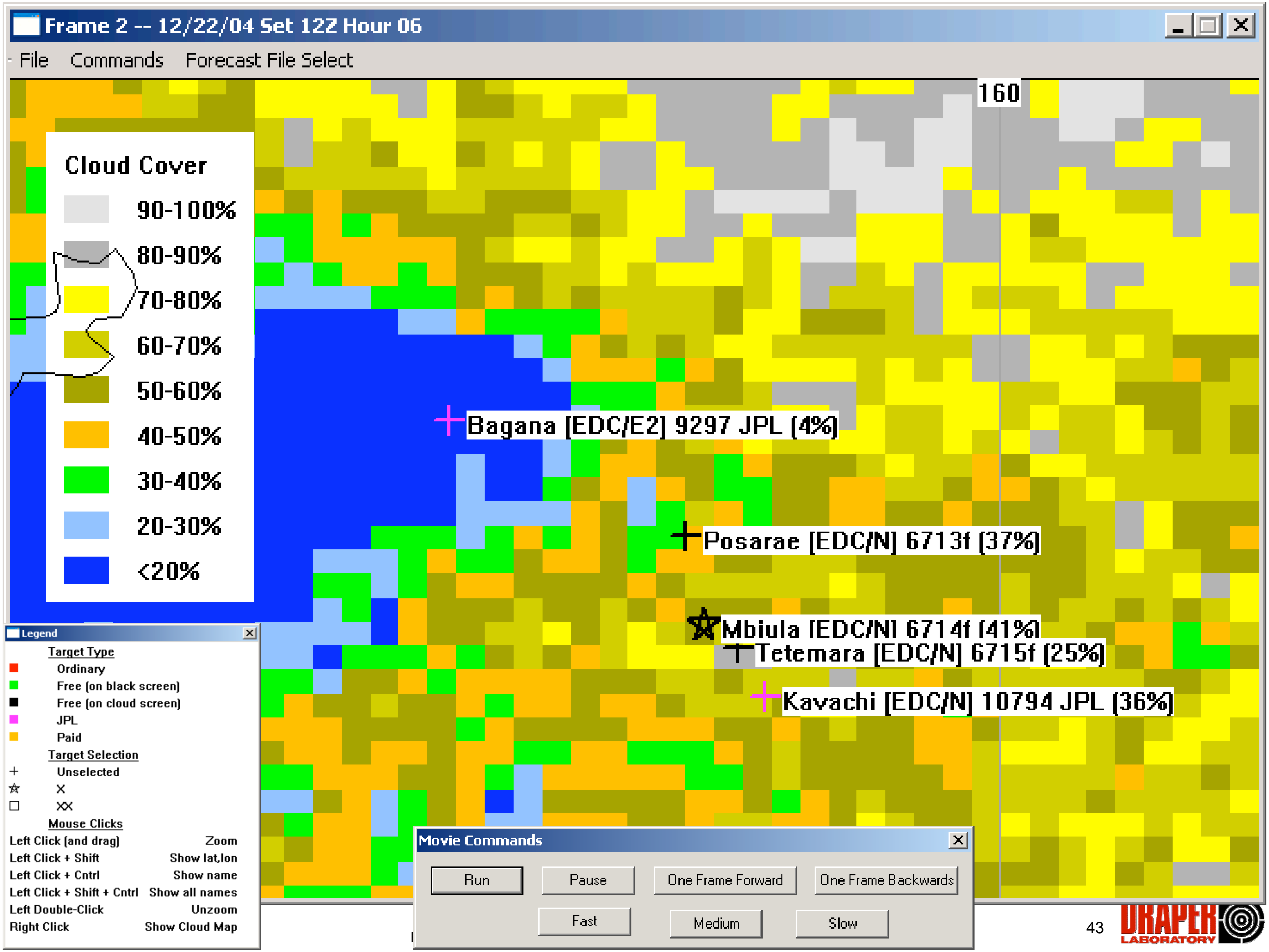
Frame 3 -- 12/22/04 Set 12Z Hour 09
File
Commands
Forecast File Select
80 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160
60
40
20
0
-20
Cloud Cover
90-100%
80-90%
70-80%
60-70%
50-60%
40-50%
30-40%
20-30%
<20%
Legend
Target Type
Ordinary
Free (on black screen)
Free (on cloud screen)
JPL
Paid
Target Selection
Unselected
X
XX
Mouse Clicks
Left Click (and drag) Zoom
Left Click + Shift Show lat,lon
Left Click + Cntrl Show name
Left Click + Shift + Cntrl Show all names
Left Double-Click Unzoom
Right Click Show Cloud Map
Movie Commands
Run
Pause
One Frame Forward
One Frame Backwards
Fast
Medium
Slow

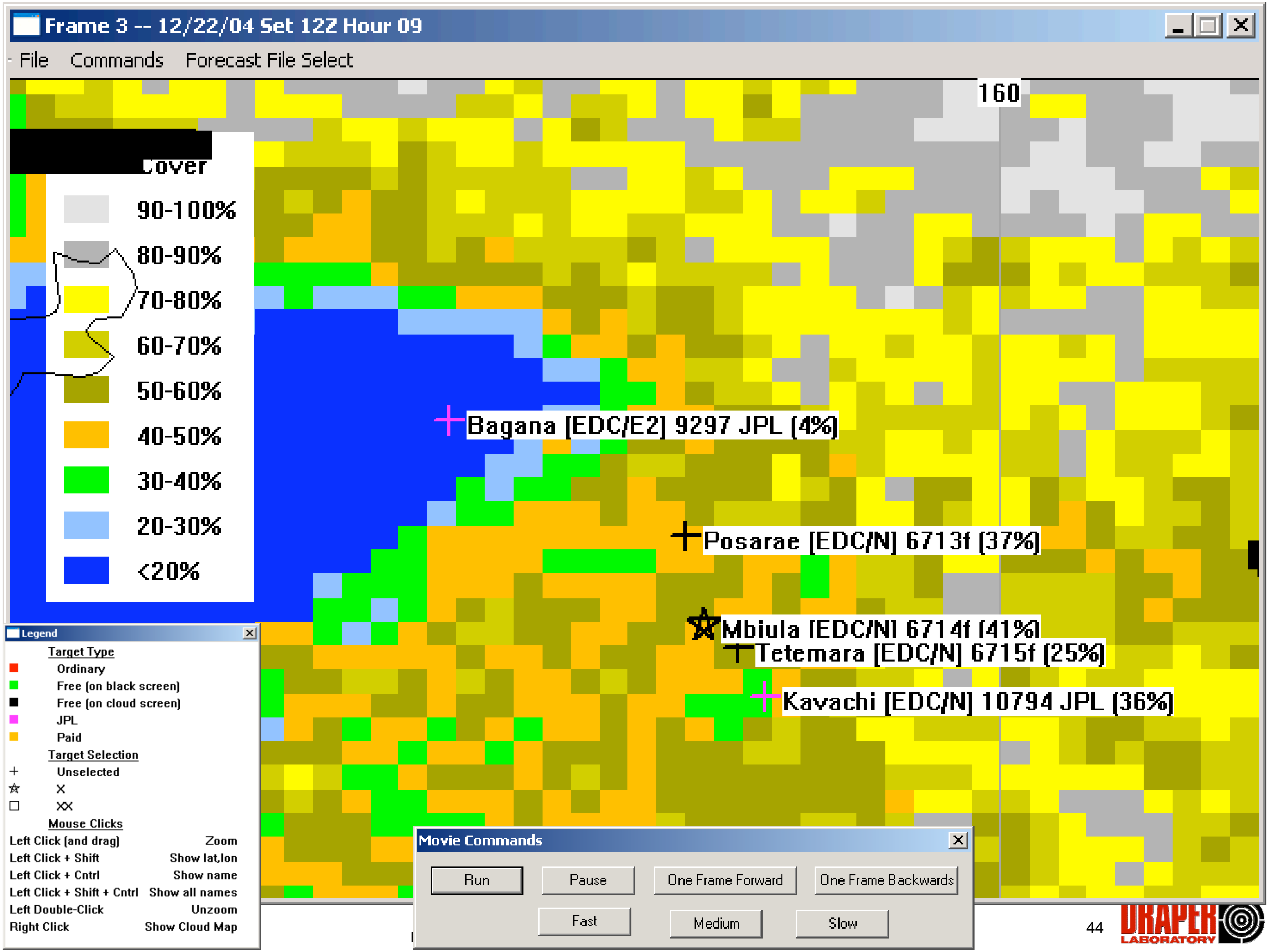

Frame 4 -- -842150451/-842150451/-842152451 Set -842150451Z Hour -842150451
File
Commands
Forecast File Select
80
-160
-140
-120
-100
-80
-60
-40
-20
0
20
40
60
80
100
120
140
160
60
40
20
0
-20
Cloud Cover
90-100%
80-90%
70-80%
60-70%
50-60%
40-50%
30-40%
20-30%
<20%
Legend
Target Type
Ordinary
Free (on black screen)
Free (on cloud screen)
JPL
Paid
Target Selection
Unselected
X
XX
Mouse Clicks
Left Click (and drag) Zoom
Left Click + Shift Show lat,lon
Left Click + Cntrl Show name
Left Click + Shift + Cntrl Show all names
Left Double-Click Unzoom
Right Click Show Cloud Map
Movie Commands
Run
Pause
One Frame Forward
One Frame Backwards
Fast
Medium
Slow



Frame 0 -- 12/22/04 Set 12Z Hour 00
File
Commands
Forecast File Select
160
Cloud Cover
90-100%
80-90%
70-80%
60-70%
50-60%
40-50%
30-40%
20-30%
<20%
Bagana [EDC/E2] 9297 JPL [4%]
Posarae [EDC/N] 6713f [37%]
Mbiula [EDC/N] 6714f [41%]
Tetemara [EDC/N] 6715f [25%]
Kavachi [EDC/N] 10794 JPL [36%]
Legend
Target Type
Ordinary
Free (on black screen)
Free (on cloud screen)
JPL
Paid
Target Selection
Unselected
X
XX
Mouse Clicks
Left Click (and drag) Zoom
Left Click + Shift Show lat,lon
Left Click + Cntrl Show name
Left Click + Shift + Cntrl Show all names
Left Double-Click Unzoom
Right Click Show Cloud Map
Movie Commands
Run
Pause
One Frame Forward
One Frame Backwards
Fast
Medium
Slow


Frame 1 -- 12/22/04 Set 12Z Hour 03
File
Commands
Forecast File Select
160
Cloud Cover
90-100%
80-90%
70-80%
60-70%
50-60%
40-50%
30-40%
20-30%
<20%
Bagana [EDC/E2] 9297 JPL (4%)
Posarae [EDC/N] 6713f (37%)
Mbiula [EDC/N] 6714f (41%)
Tetemara [EDC/N] 6715f (25%)
Kavachi [EDC/N] 10794 JPL (36%)
Legend
Target Type
Ordinary
Free (on black screen)
Free (on cloud screen)
JPL
Paid
Target Selection
Unselected
X
XX
Mouse Clicks
Left Click (and drag) Zoom
Left Click + Shift Show lat,lon
Left Click + Cntrl Show name
Left Click + Shift + Cntrl Show all names
Left Double-Click Unzoom
Right Click Show Cloud Map
Movie Commands
Run
Pause
One Frame Forward
One Frame Backwards
Fast
Medium
Slow


Frame 2 -- 12/22/04 Set 12Z Hour 06
File
Commands
Forecast File Select
160
Cloud Cover
90-100%
80-90%
70-80%
60-70%
50-60%
40-50%
30-40%
20-30%
<20%
Bagana [EDC/E2] 9297 JPL (4%)
Posarae [EDC/N] 6713f (37%)
Mbiula [EDC/N] 6714f (41%)
Tetemara [EDC/N] 6715f (25%)
Kavachi [EDC/N] 10794 JPL (36%)
Legend
Target Type
Ordinary
Free (on black screen)
Free (on cloud screen)
JPL
Paid
Target Selection
Unselected
X
XX
Mouse Clicks
Left Click (and drag) Zoom
Left Click + Shift Show lat,lon
Left Click + Cntrl Show name
Left Click + Shift + Cntrl Show all names
Left Double-Click Unzoom
Right Click Show Cloud Map
Movie Commands
Run
Pause
One Frame Forward
One Frame Backwards
Fast
Medium
Slow



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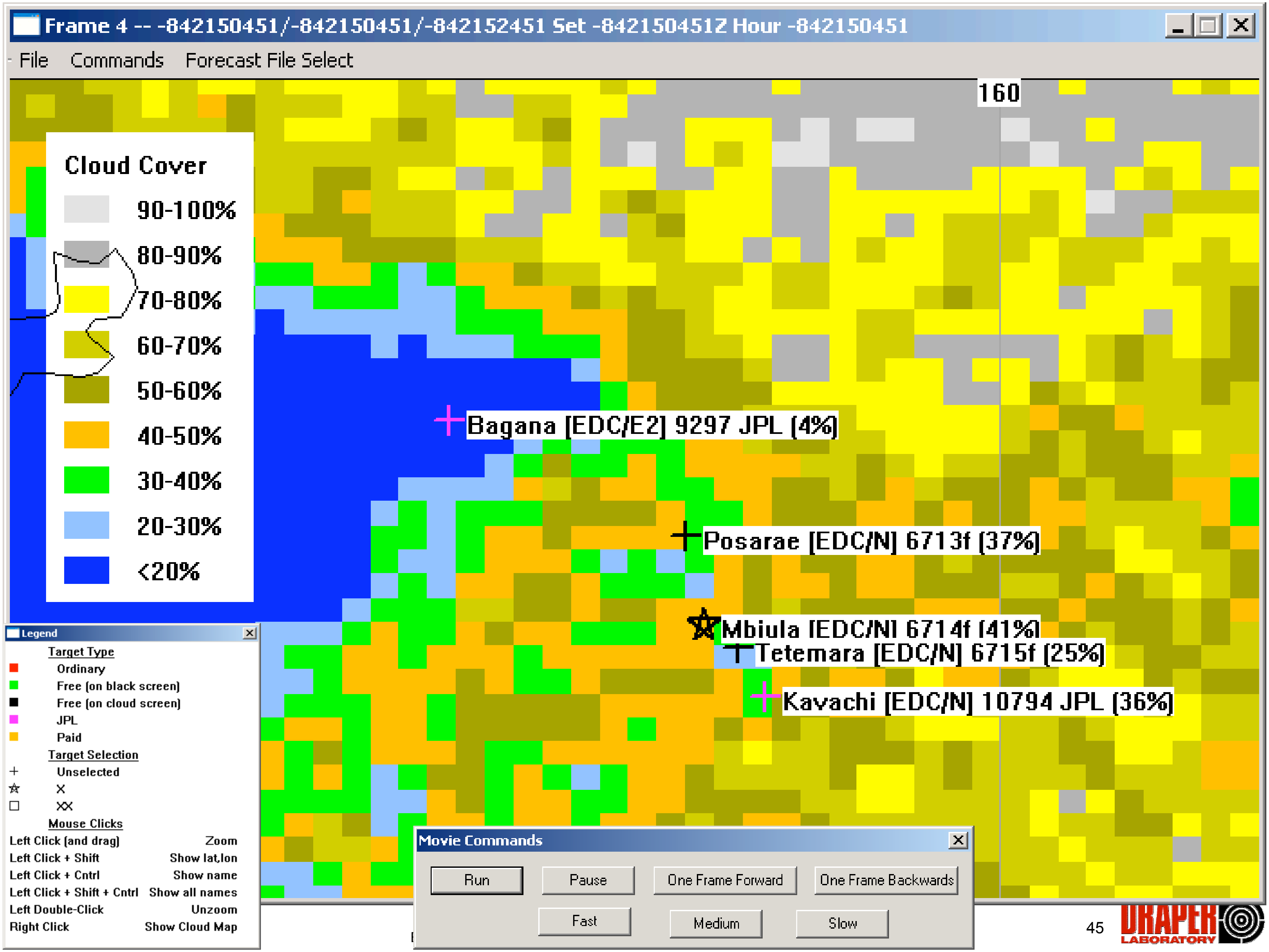
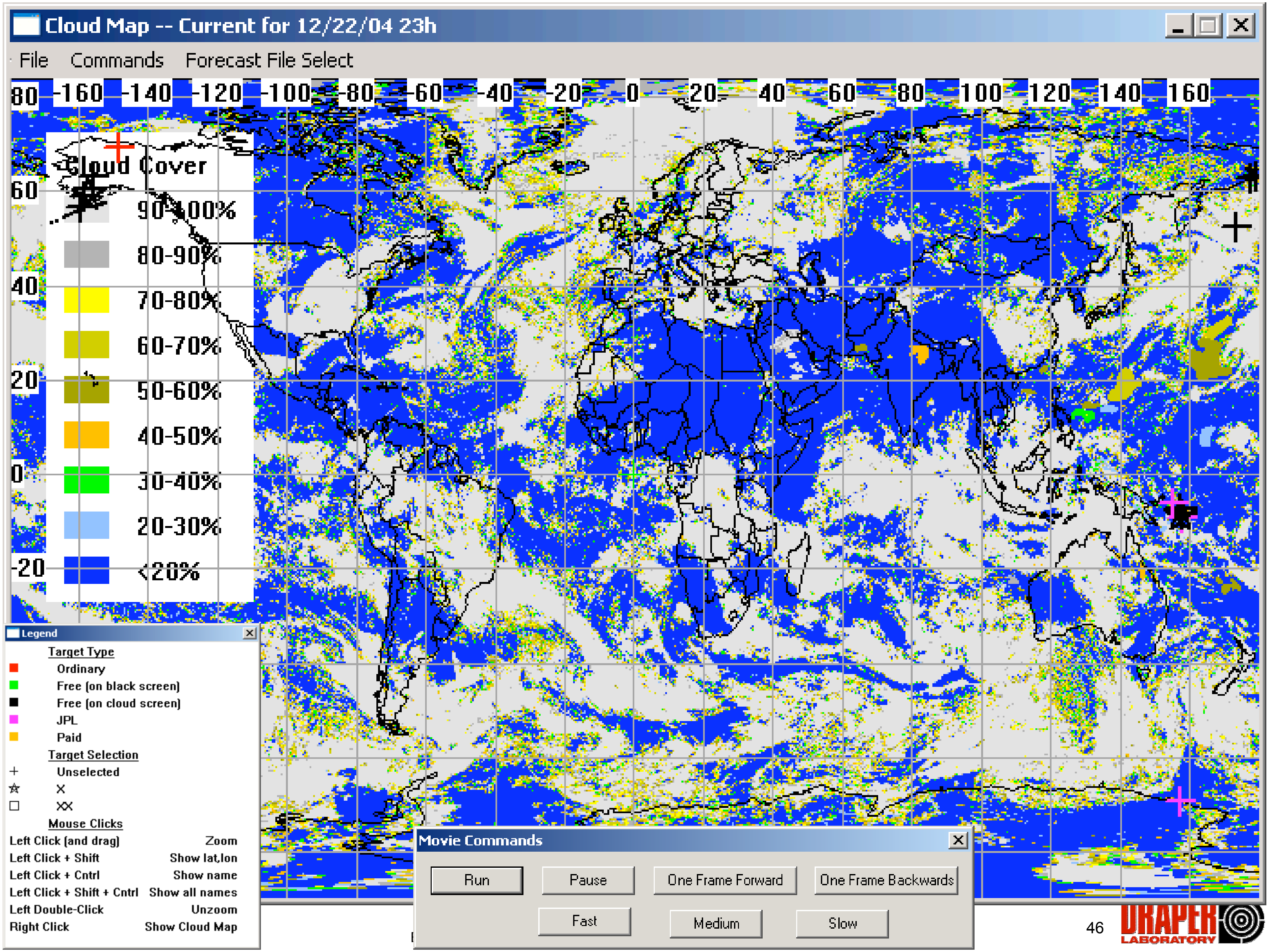
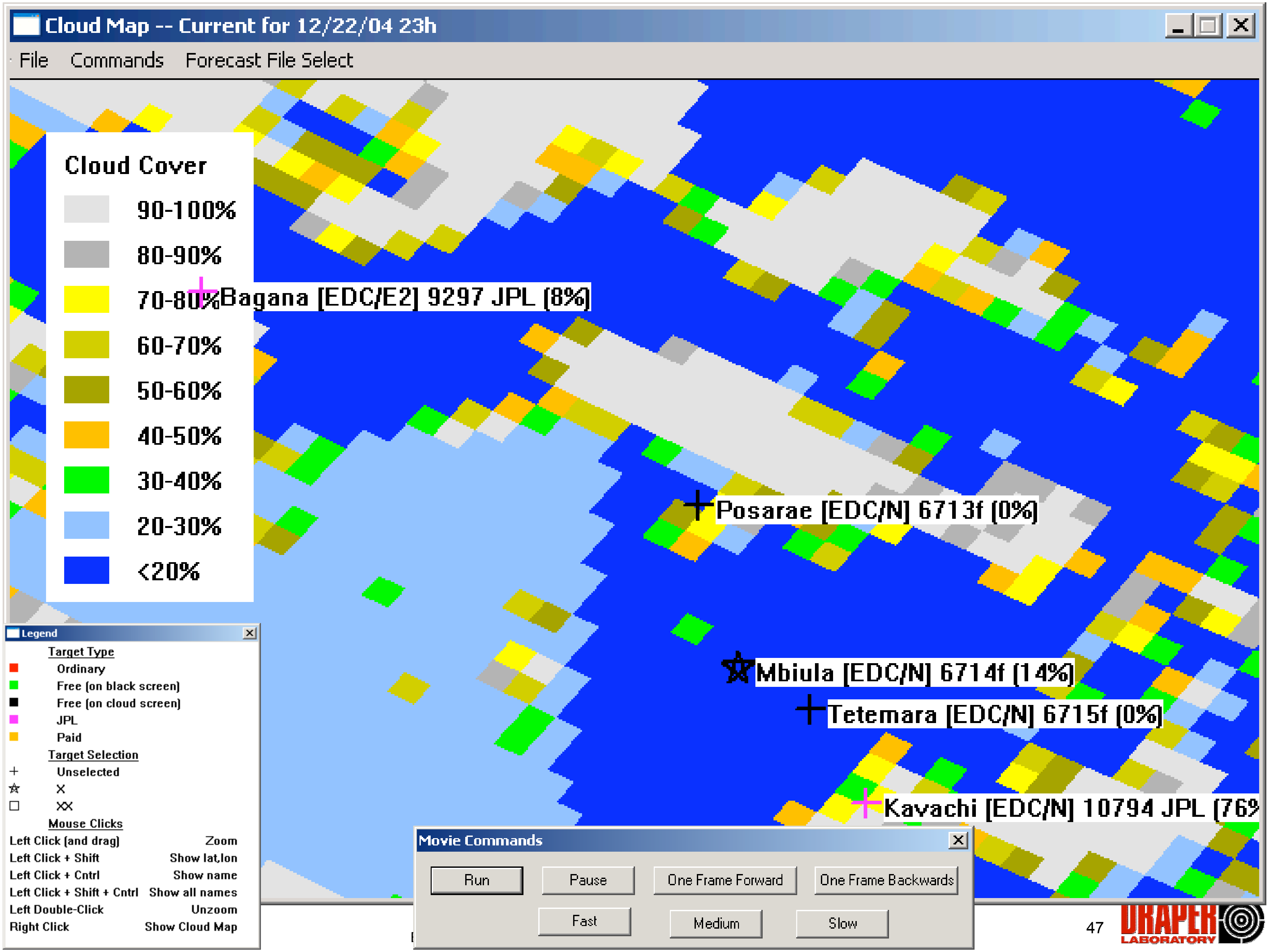


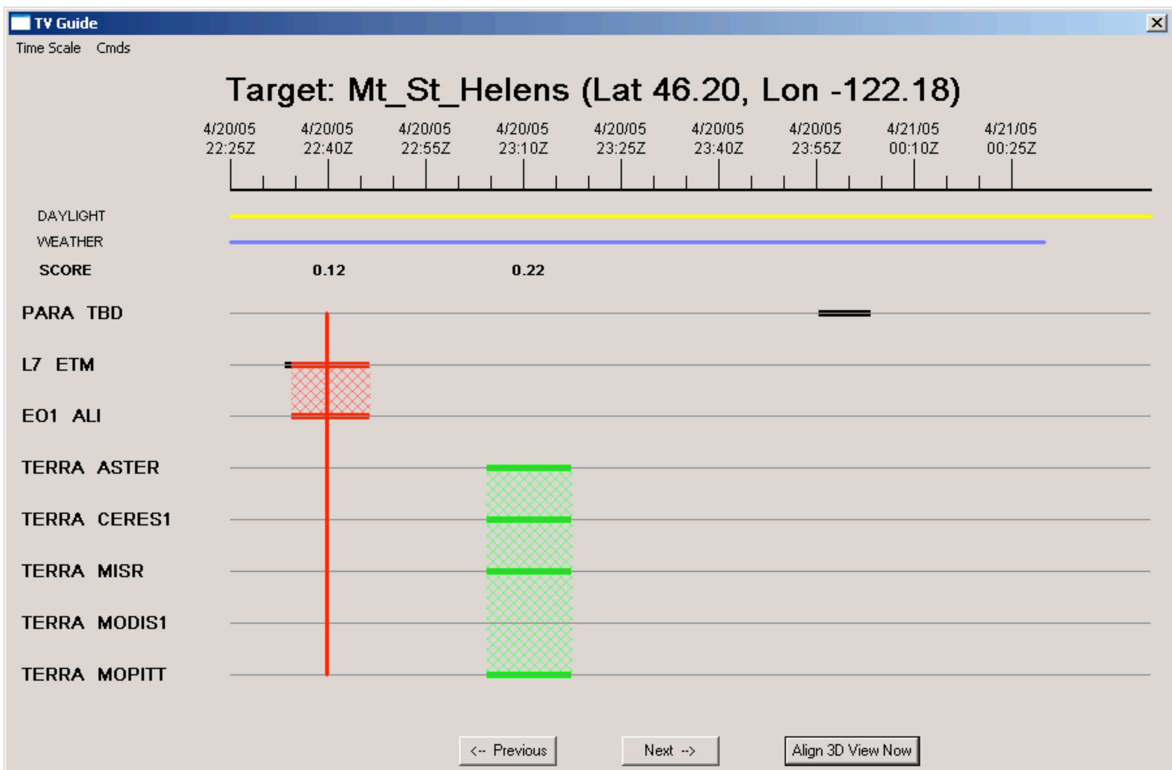
Frame 4 -- -842150451/-842150451/-842152451 Set -842150451Z Hour -842150451
File
Commands
Forecast File Select
160
Cloud Cover
90-100%
80-90%
70-80%
60-70%
50-60%
40-50%
30-40%
20-30%
<20%
Bagana [EDC/E2] 9297 JPL (4%)
Posarae [EDC/N] 6713f (37%)
Mbiula [EDC/N] 6714f (41%)
Tetemara [EDC/N] 6715f (25%)
Kavachi [EDC/N] 10794 JPL (36%)
Legend
Target Type
Ordinary
Free (on black screen)
Free (on cloud screen)
JPL
Paid
Target Selection
Unselected
X
XX
Mouse Clicks
Left Click (and drag) Zoom
Left Click + Shift Show lat,lon
Left Click + Cntrl Show name
Left Click + Shift + Cntrl Show all names
Left Double-Click Unzoom
Right Click Show Cloud Map
Movie Commands
Run
Pause
One Frame Forward
One Frame Backwards
Fast
Medium
Slow


Cloud Map -- Current for 12/22/04 23h
File
Commands
Forecast File Select
-160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160
80 60 40 20 0 -20
Cloud Cover
90-100%
80-90%
70-80%
60-70%
50-60%
40-50%
30-40%
20-30%
<20%
Legend
Target Type
Ordinary
Free (on black screen)
Free (on cloud screen)
JPL
Paid
Target Selection
Unselected
X
XX
Mouse Clicks
Left Click (and drag) Zoom
Left Click + Shift Show lat,lon
Left Click + Cntrl Show name
Left Click + Shift + Cntrl Show all names
Left Double-Click Unzoom
Right Click Show Cloud Map
Movie Commands
Run
Pause
One Frame Forward
One Frame Backwards
Fast
Medium
Slow


Cloud Map -- Current for 12/22/04 23h
File
Commands
Forecast File Select
Cloud Cover
90-100%
80-90%
70-80%
60-70%
50-60%
40-50%
30-40%
20-30%
<20%
Bagana [EDC/E2] 9297 JPL (8%)
Posarae [EDC/N] 6713f (0%)
Mbiula [EDC/N] 6714f (14%)
Tetemara [EDC/N] 6715f (0%)
Kavachi [EDC/N] 10794 JPL (76
Legend
Target Type
Ordinary
Free (on black screen)
Free (on cloud screen)
JPL
Paid
Target Selection
Unselected
X
XX
Mouse Clicks
Left Click (and drag) Zoom
Left Click + Shift Show lat,lon
Left Click + Cntrl Show name
Left Click + Shift + Cntrl Show all names
Left Double-Click Unzoom
Right Click Show Cloud Map
Movie Commands
Run
Pause
One Frame Forward
One Frame Backwards
Fast
Medium
Slow

TV Guide

- **A new display is being developed to highlight the opportunities for simultaneous or near-simultaneous viewing of a target from multiple satellite sensors**
  - This display has the form of an extended scrollable time line
  - This chart is optionally synchronized with STK, so the positions and sightings of the chosen satellites at any time can be displayed in 3D in an STK window



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Other Work in Progress

Improve Use of Forecast Data

- **Currently use a independent stationary point estimate and equal priority targets to choose from**

- **Work starting to:**
  – Take advantage of correlations, both spatial and temporal
  – Develop algorithm for handling unequal priority targets

TES and EO-1 Views

- Significant number of possible near-simultaneous views of active volcanoes by EO-1 and TES during a 16-day repeat cycle