Design Trades for Mission/DSN Antenna Supportability Using TIGRAS

Yeou-Fang Wang, Ph.D.
Chet Borden
John Kehrbaum
JPL/CalTech/NASA

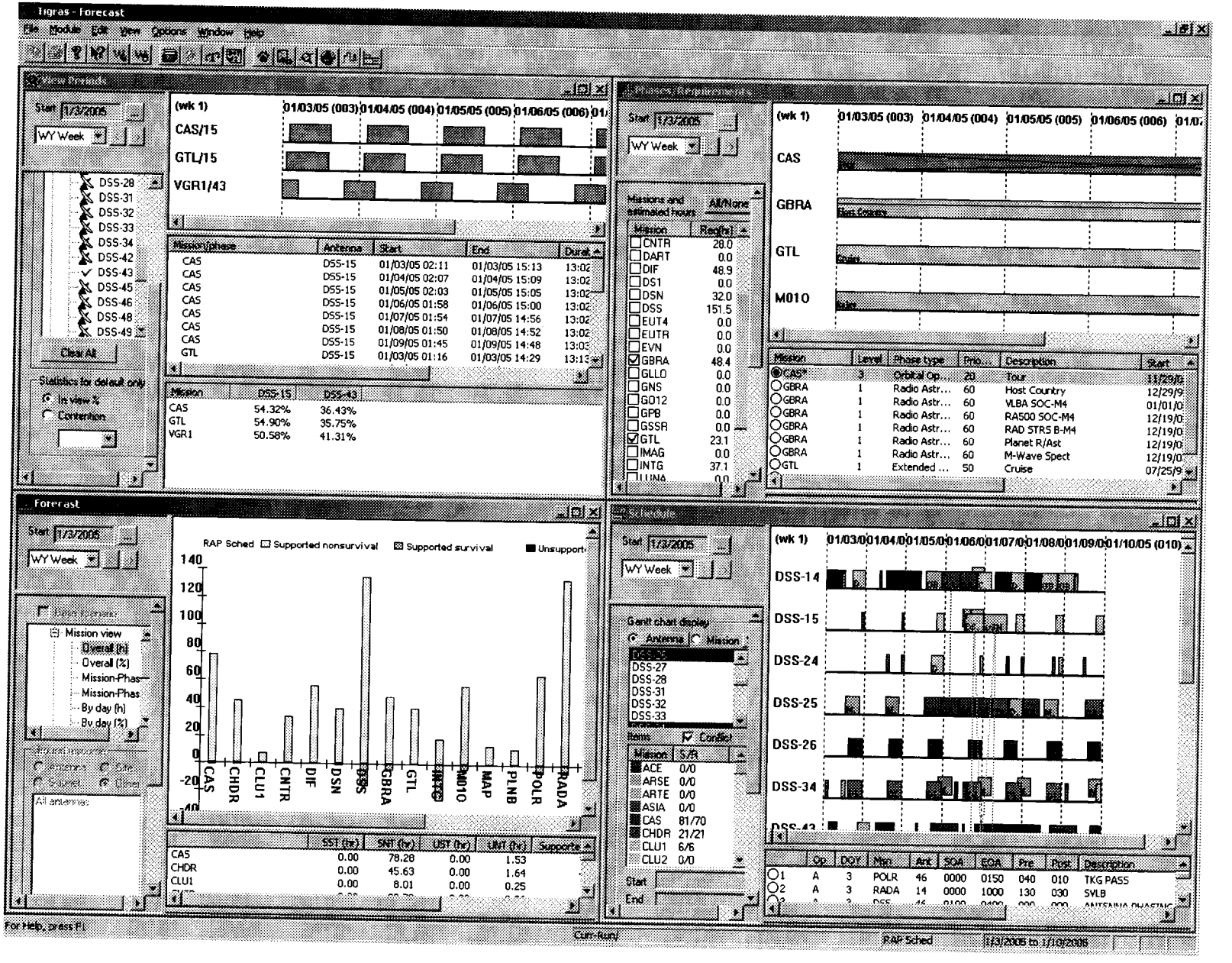
Background

- Mission ops considerations are not adequately considered early in the mission/spacecraft design life cycle
  - In particular, Mission/DSN antenna supportability analysis is not addressed
- TIGRAS SW forecasts DSN ground system ability to support space flight missions based on:
  - User (flight project and ground operations) requirements for antenna resources over time and
  - Mission design parameters (e.g., project viewperiods)
- TIGRAS allows consideration of ground support as a mission design variable and can be included as an element of mission design trades

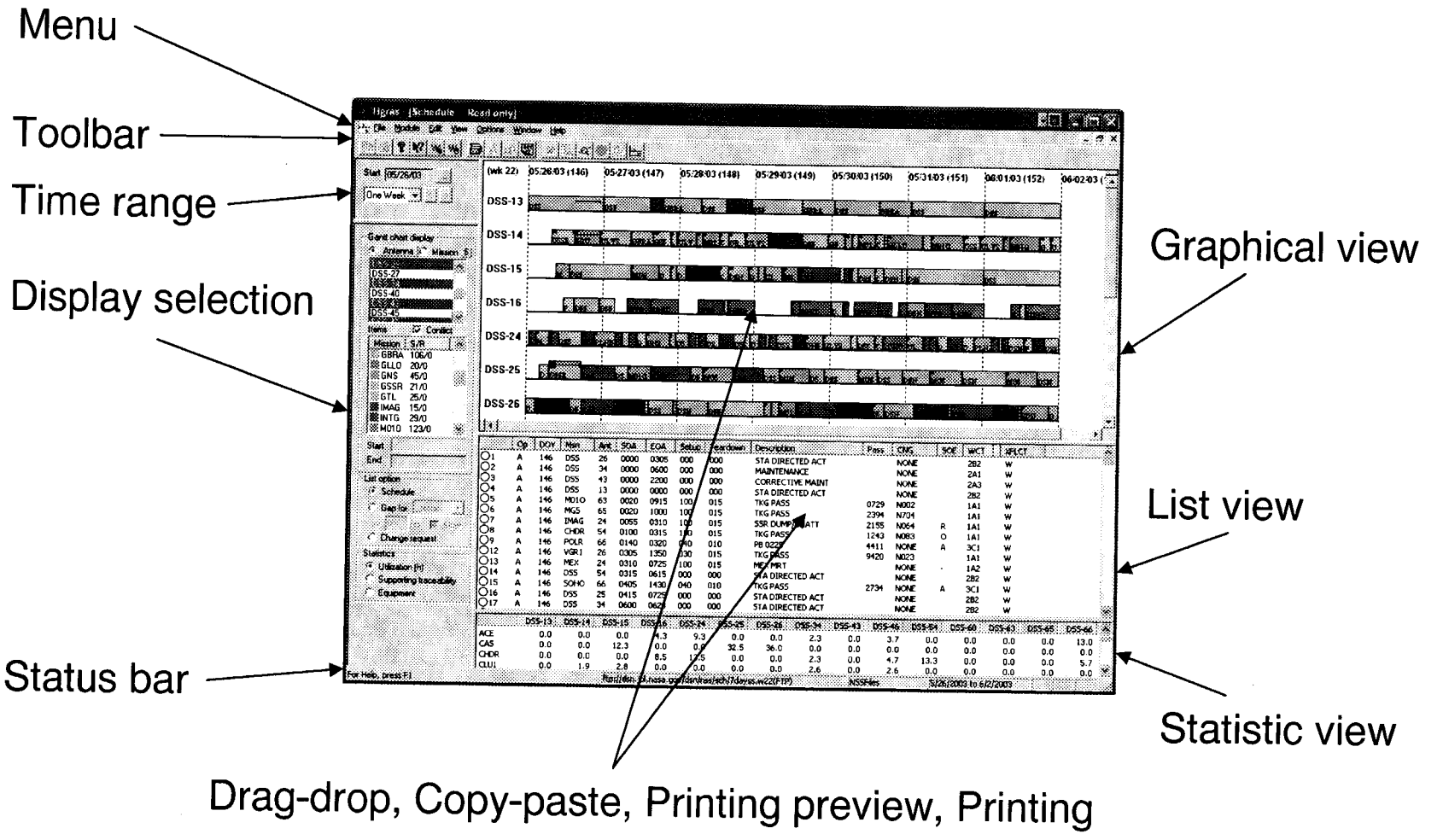
TIGRAS

- TMOD Integrated Ground Resource Allocation and Scheduling tool
  - Mission/DSN Ground system supportability forecasting and capacity planning
  - Resource scheduling
- Integrated Analysis Environment (IAE)
  - Viewing requirements, constraints, results
  - Graphics and text
  - Forecast and scheduling analysis
- Microsoft Visual C++ / MFC, Excel/VBA

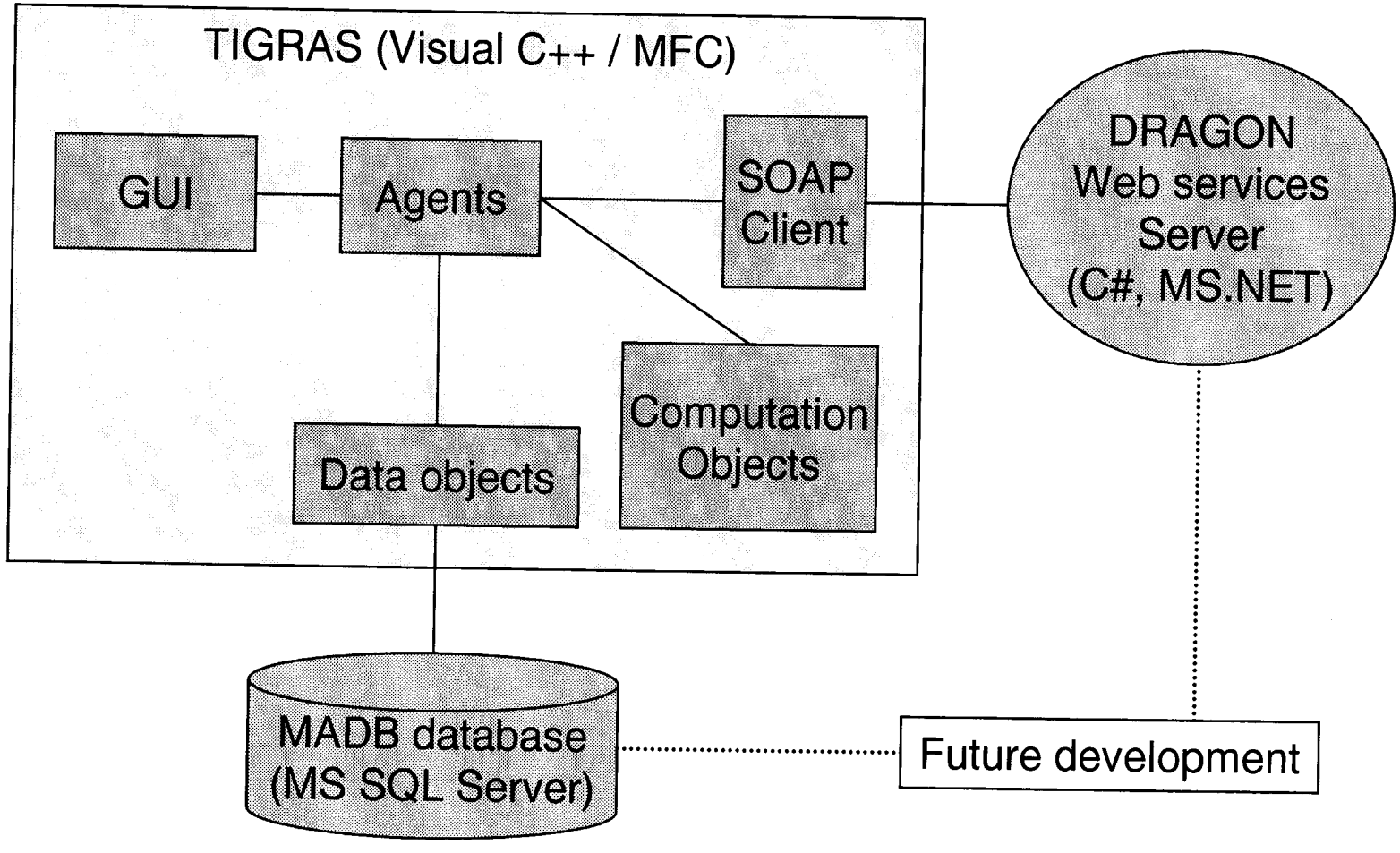
TIGRAS Integrated Analysis Environment



TIGRAS Window



TIGRAS Architecture



TIGRAS Major Algorithms

- Ground resource load forecast
  - Given project resource requirements (including continuous, arraying, segmentation, ...)
  - Given view period, downtime, constraints, ...
  - Distributes multiple simultaneous demands over available resources while considering priority, constraints, and fairness
  - Identify high contention area for further analysis
- Ground resource scheduling
  - Given resource requirements and constraints
  - Generate a "conflict-aware" schedule using various concepts from gradient-descent, heuristics, simulated annealing, fuzzy logic, ...
  - Perform conflict-checking based on defined rules

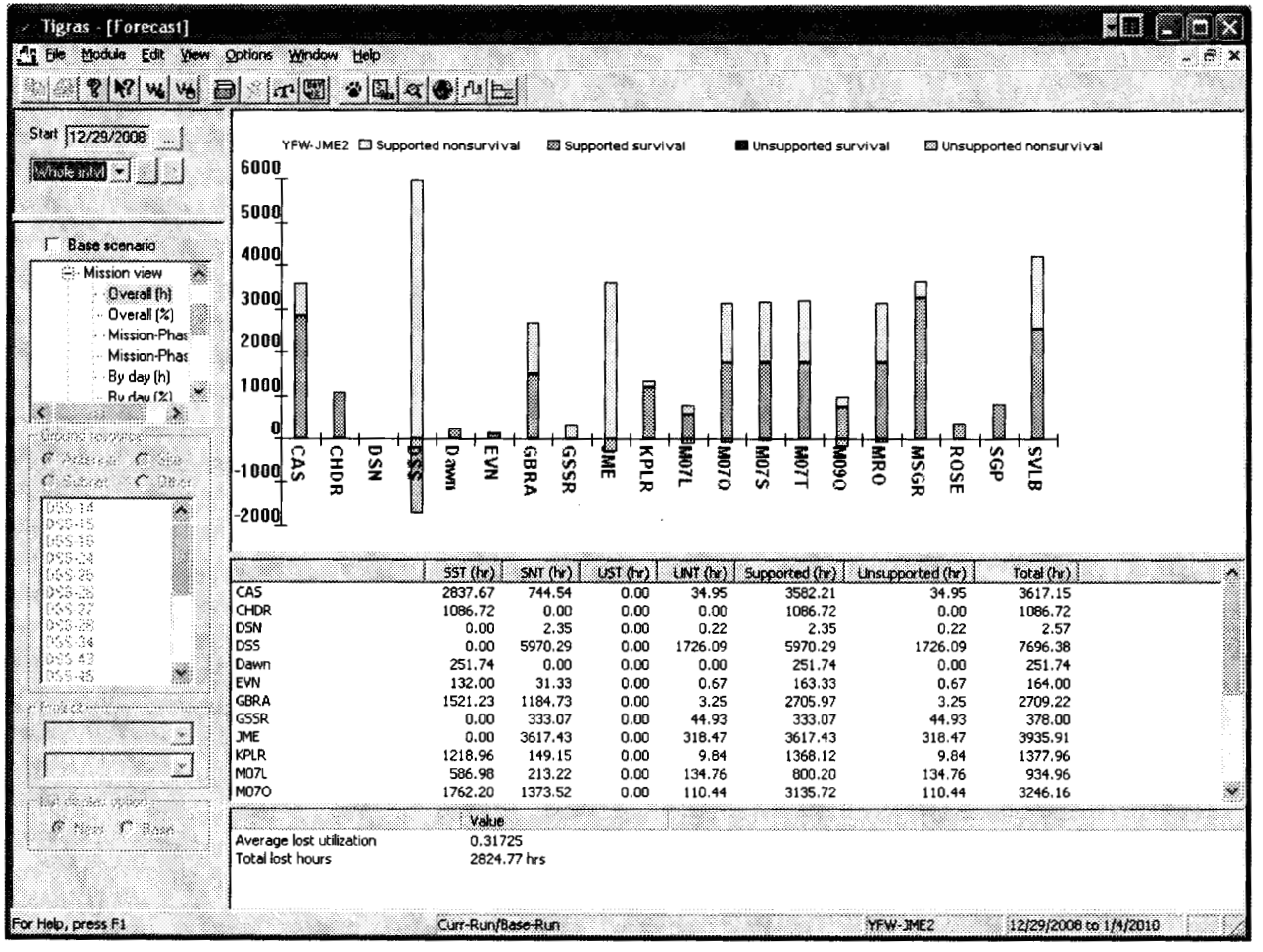
TIGRAS Target Users
One environment for all users

- Current:
  - Ground resource allocation and capacity planners
  - Mid-range schedulers
  - Near-real-time schedulers
- Future:
  - ***Project designers*** ***(focus of this presentation)***
  - Project schedulers
  - Ground operators

Spacecraft Supportability Analysis

TIGRAS provides a wide variety of views for analysis

Supportability by Mission

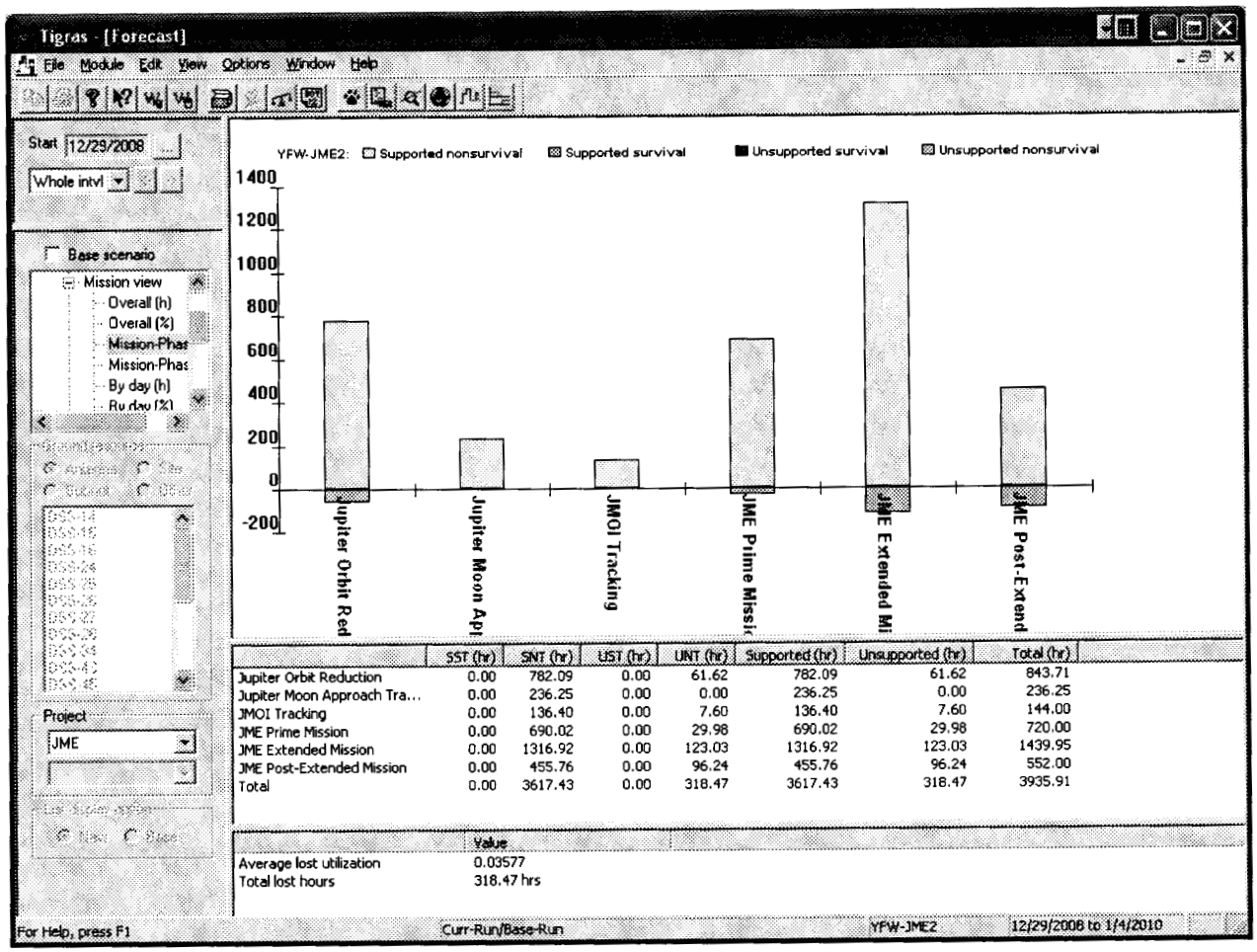


	SST (hr)	SNT (hr)	UST (hr)	UNT (hr)	Supported (hr)	Unsupported (hr)	Total (hr)
CAS	2837.67	744.54	0.00	34.95	3582.21	34.95	3617.15
CHDR	1086.72	0.00	0.00	0.00	1086.72	0.00	1086.72
DSN	0.00	2.35	0.00	0.22	2.35	0.22	2.57
DSS	0.00	5970.29	0.00	1726.09	5970.29	1726.09	7696.38
Dawn	251.74	0.00	0.00	0.00	251.74	0.00	251.74
EVN	132.00	31.33	0.00	0.67	163.33	0.67	164.00
GBRA	1521.23	1184.73	0.00	3.25	2705.97	3.25	2709.22
GSSR	0.00	333.07	0.00	44.93	333.07	44.93	378.00
JME	0.00	3617.43	0.00	318.47	3617.43	318.47	3935.91
KPLR	1218.96	149.15	0.00	9.84	1368.12	9.84	1377.96
M07L	586.98	213.22	0.00	134.76	800.20	134.76	934.96
M07O	1762.20	1373.52	0.00	110.44	3135.72	110.44	3246.16

	Value
Average lost utilization	0.31725
Total lost hours	2824.77 hrs

*Hypothetical data for illustration only

Supportability by Major Events

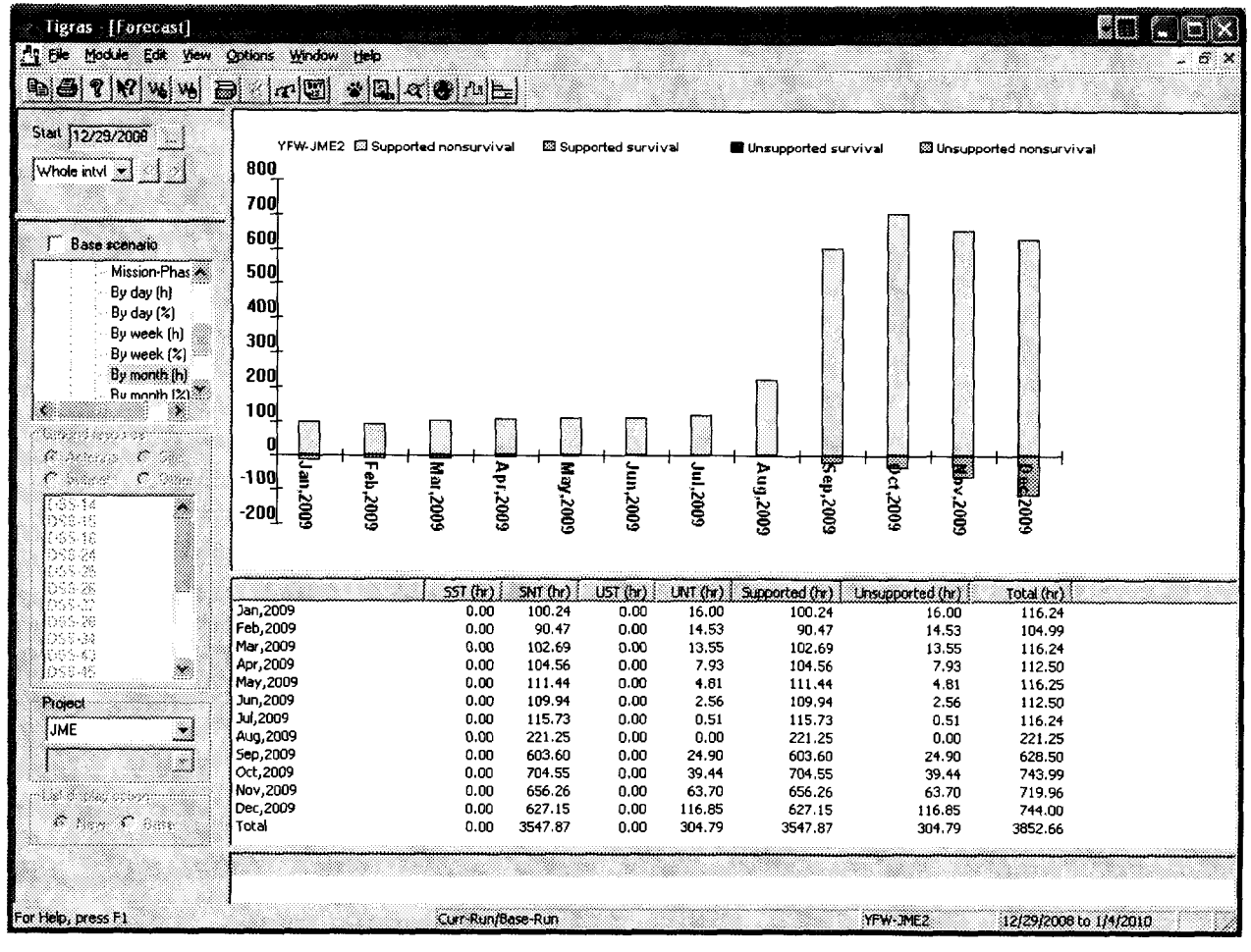


	SST (hr)	SNT (hr)	UST (hr)	UNT (hr)	Supported (hr)	Unsupported (hr)	Total (hr)
Jupiter Orbit Reduction	0.00	782.09	0.00	61.62	782.09	61.62	843.71
Jupiter Moon Approach Tra...	0.00	236.25	0.00	0.00	236.25	0.00	236.25
JMOI Tracking	0.00	136.40	0.00	7.60	136.40	7.60	144.00
JME Prime Mission	0.00	690.02	0.00	29.98	690.02	29.98	720.00
JME Extended Mission	0.00	1316.92	0.00	123.03	1316.92	123.03	1439.95
JME Post-Extended Mission	0.00	455.76	0.00	96.24	455.76	96.24	552.00
Total	0.00	3617.43	0.00	318.47	3617.43	318.47	3935.91

	Value
Average lost utilization	0.03577
Total lost hours	318.47 hrs

*Hypothetical data for illustration only

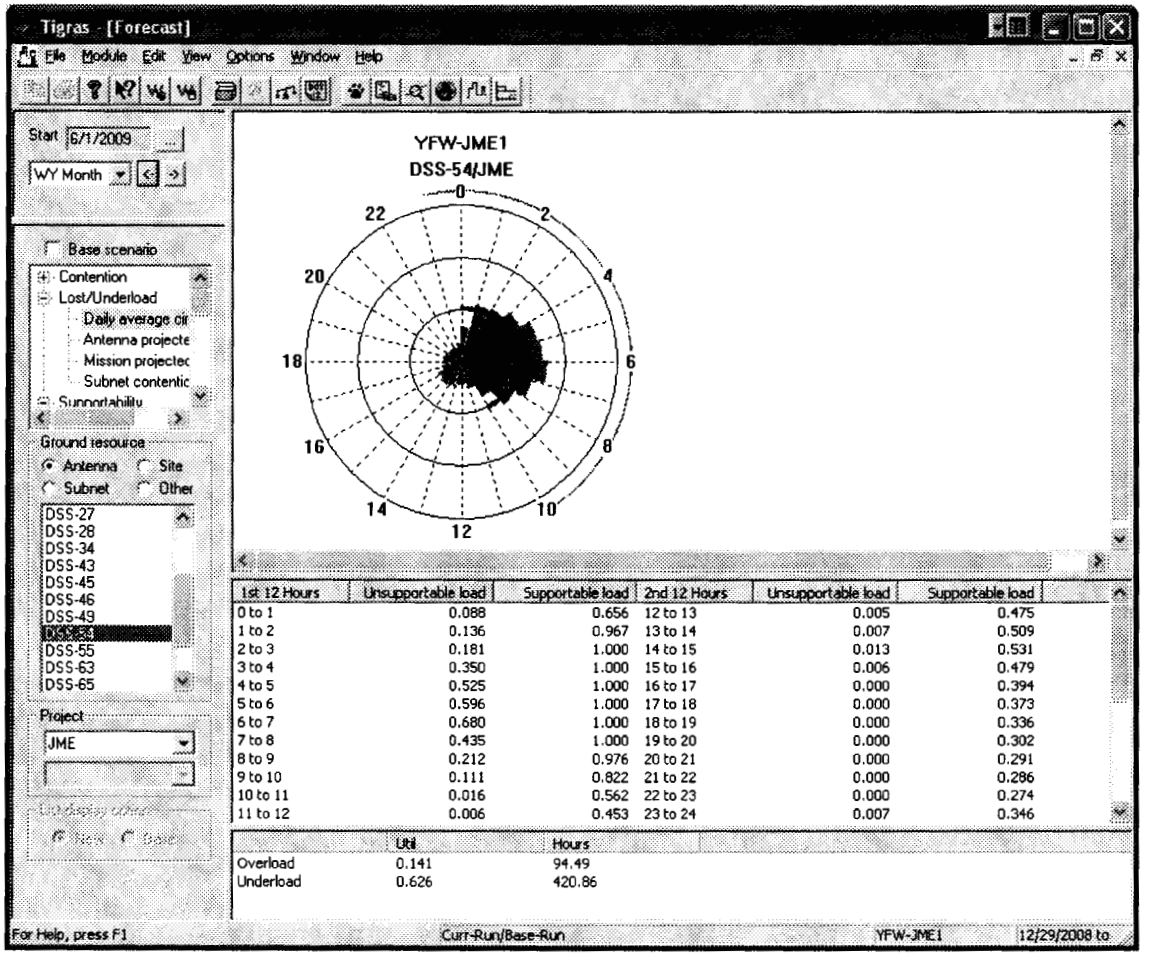
Supportability by Time



	SST (hr)	SNT (hr)	UST (hr)	UNT (hr)	Supported (hr)	Unsupported (hr)	Total (hr)
Jan,2009	0.00	100.24	0.00	16.00	100.24	16.00	116.24
Feb,2009	0.00	90.47	0.00	14.53	90.47	14.53	104.99
Mar,2009	0.00	102.69	0.00	13.55	102.69	13.55	116.24
Apr,2009	0.00	104.56	0.00	7.93	104.56	7.93	112.50
May,2009	0.00	111.44	0.00	4.81	111.44	4.81	116.25
Jun,2009	0.00	109.94	0.00	2.56	109.94	2.56	112.50
Jul,2009	0.00	115.73	0.00	0.51	115.73	0.51	116.24
Aug,2009	0.00	221.25	0.00	0.00	221.25	0.00	221.25
Sep,2009	0.00	603.60	0.00	24.90	603.60	24.90	628.50
Oct,2009	0.00	704.55	0.00	39.44	704.55	39.44	743.99
Nov,2009	0.00	656.26	0.00	63.70	656.26	63.70	719.96
Dec,2009	0.00	627.15	0.00	116.85	627.15	116.85	744.00
Total	0.00	3547.87	0.00	304.79	3547.87	304.79	3852.66

*Hypothetical data for illustration only

Daily Supportability

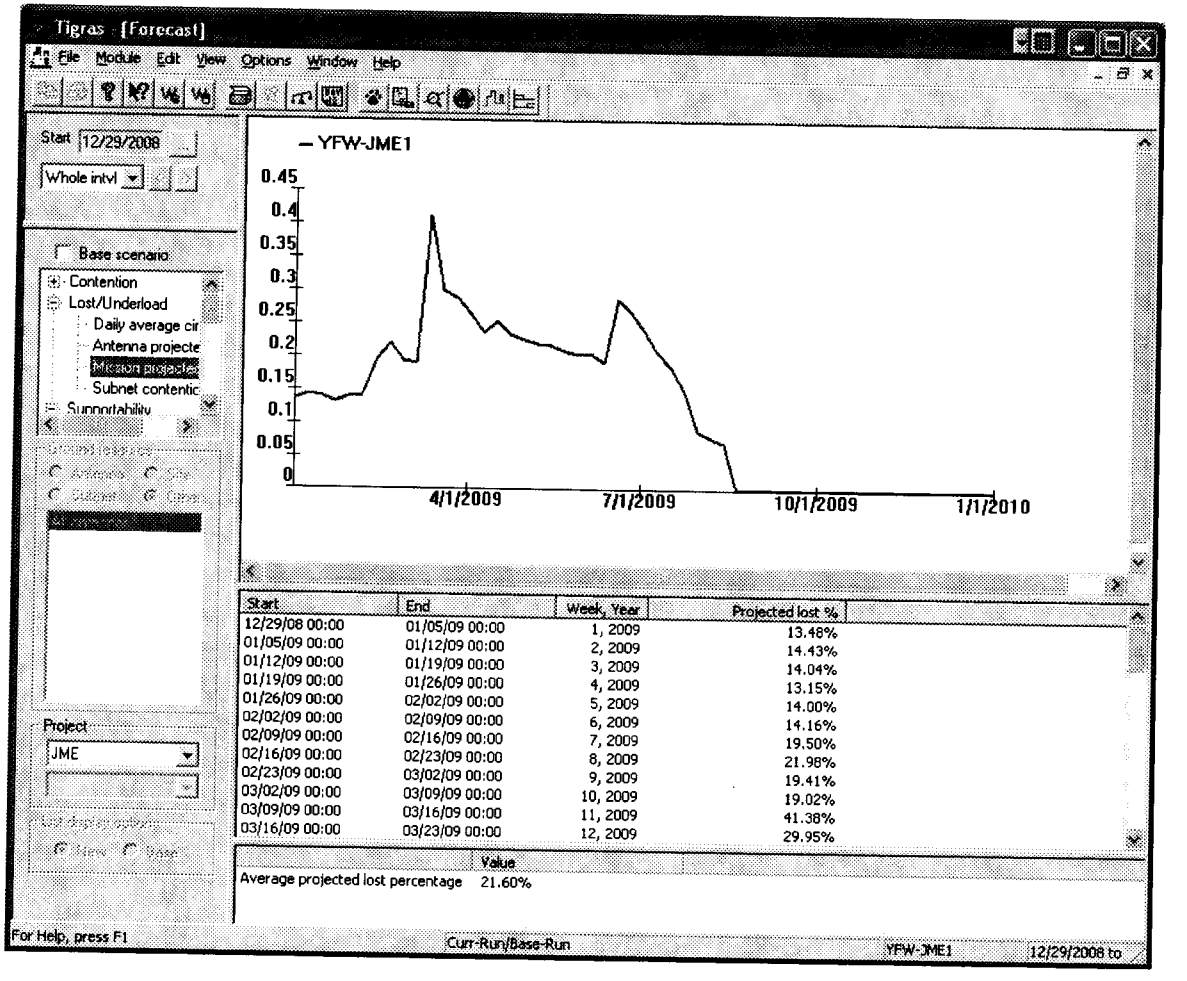


1st 12 Hours	Unsupportable load	Supportable load	2nd 12 Hours	Unsupportable load	Supportable load
0 to 1	0.088	0.656	12 to 13	0.005	0.475
1 to 2	0.136	0.967	13 to 14	0.007	0.509
2 to 3	0.181	1.000	14 to 15	0.013	0.531
3 to 4	0.350	1.000	15 to 16	0.006	0.479
4 to 5	0.525	1.000	16 to 17	0.000	0.394
5 to 6	0.596	1.000	17 to 18	0.000	0.373
6 to 7	0.680	1.000	18 to 19	0.000	0.336
7 to 8	0.435	1.000	19 to 20	0.000	0.302
8 to 9	0.212	0.976	20 to 21	0.000	0.291
9 to 10	0.111	0.822	21 to 22	0.000	0.286
10 to 11	0.016	0.562	22 to 23	0.000	0.274
11 to 12	0.006	0.453	23 to 24	0.007	0.346

	Util	Hours
Overload	0.141	94.49
Underload	0.626	420.86

*Hypothetical data for illustration only

Mission Projected Lost Time



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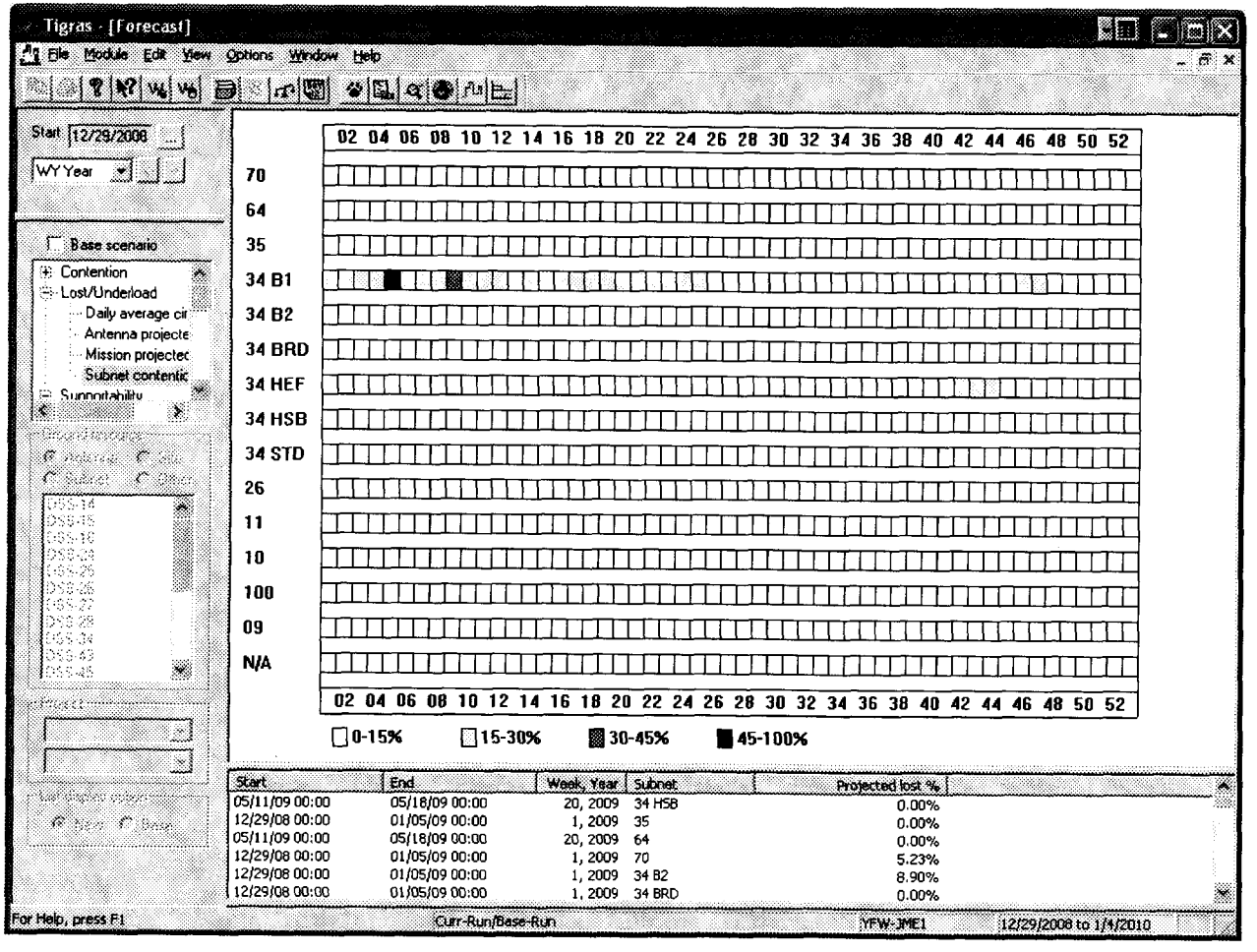
Subnet Contention



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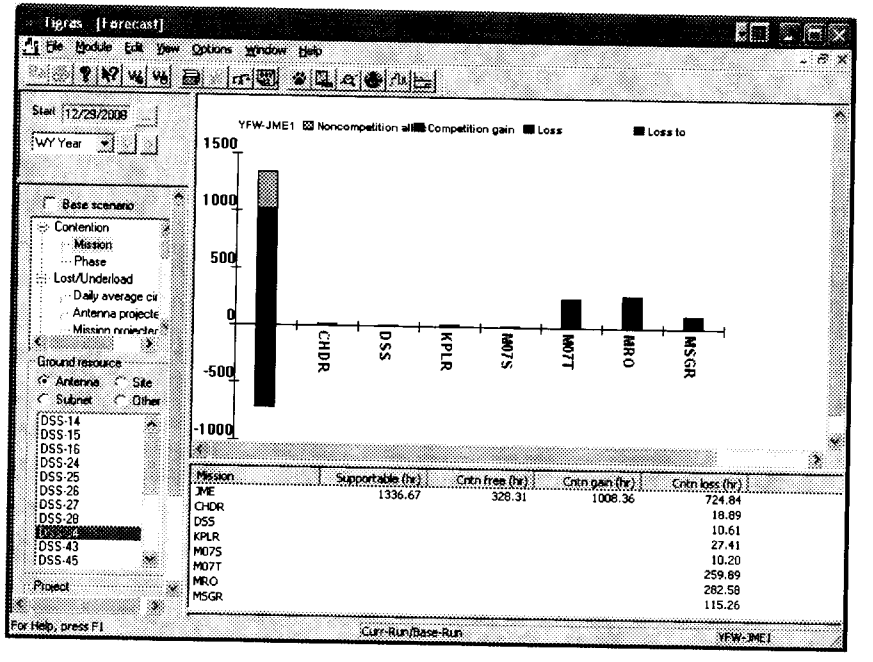
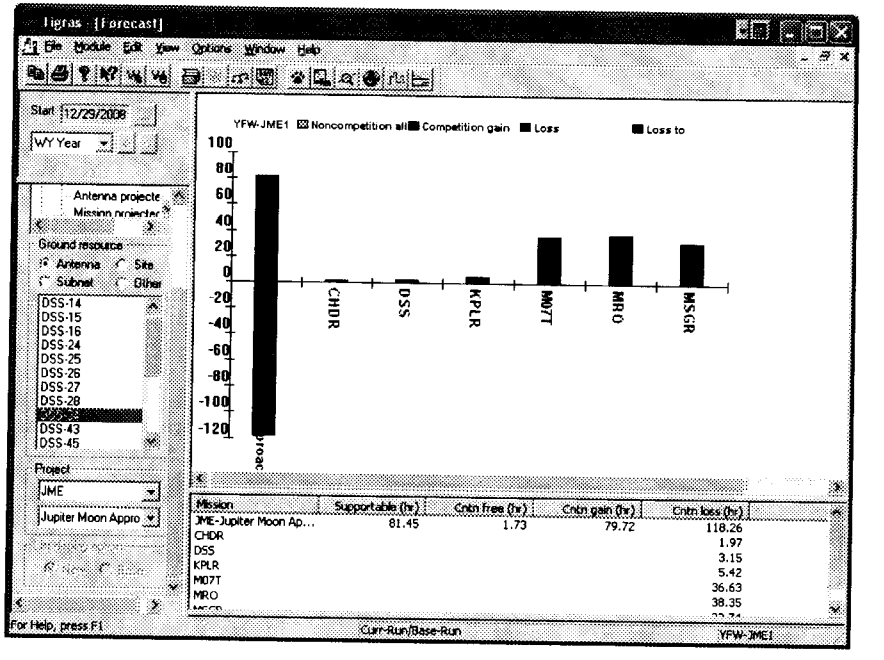
Mission Contention

Mission contention



Phase contention



*Hypothetical data for illustration only

Usage Example:

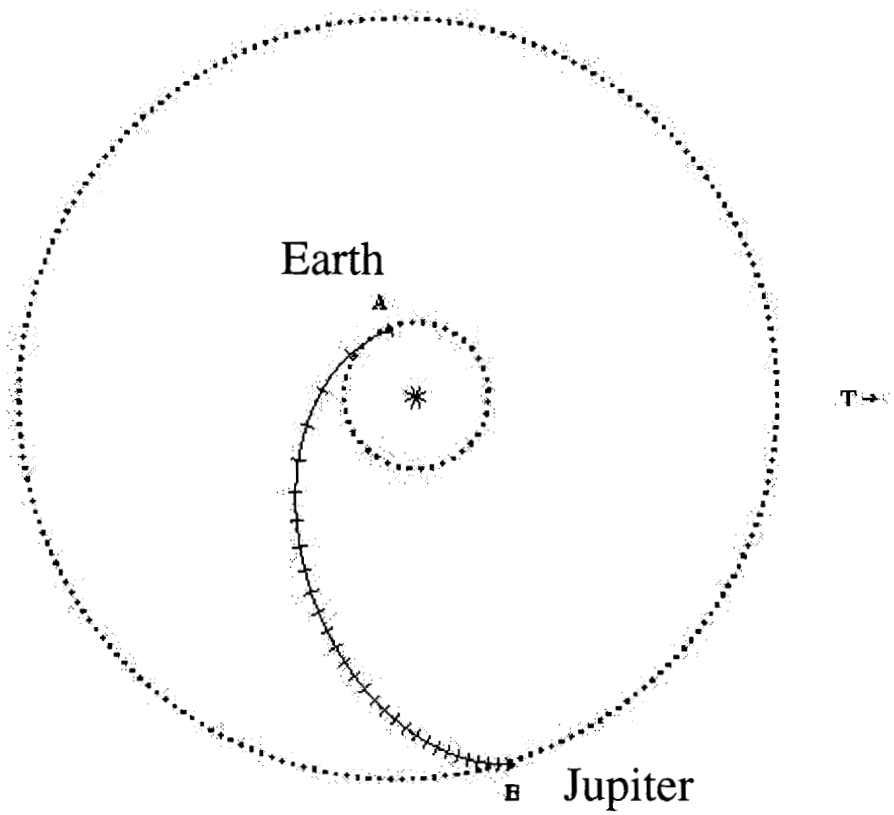
Antenna Load Forecast for Early Mission Design

Hypothetical mission:

Jovian Moon Explorer (JME)

Hypothetical mission: Jovian Moon Explorer (JME)

Example of The Direct Earth-Jupiter Trajectory

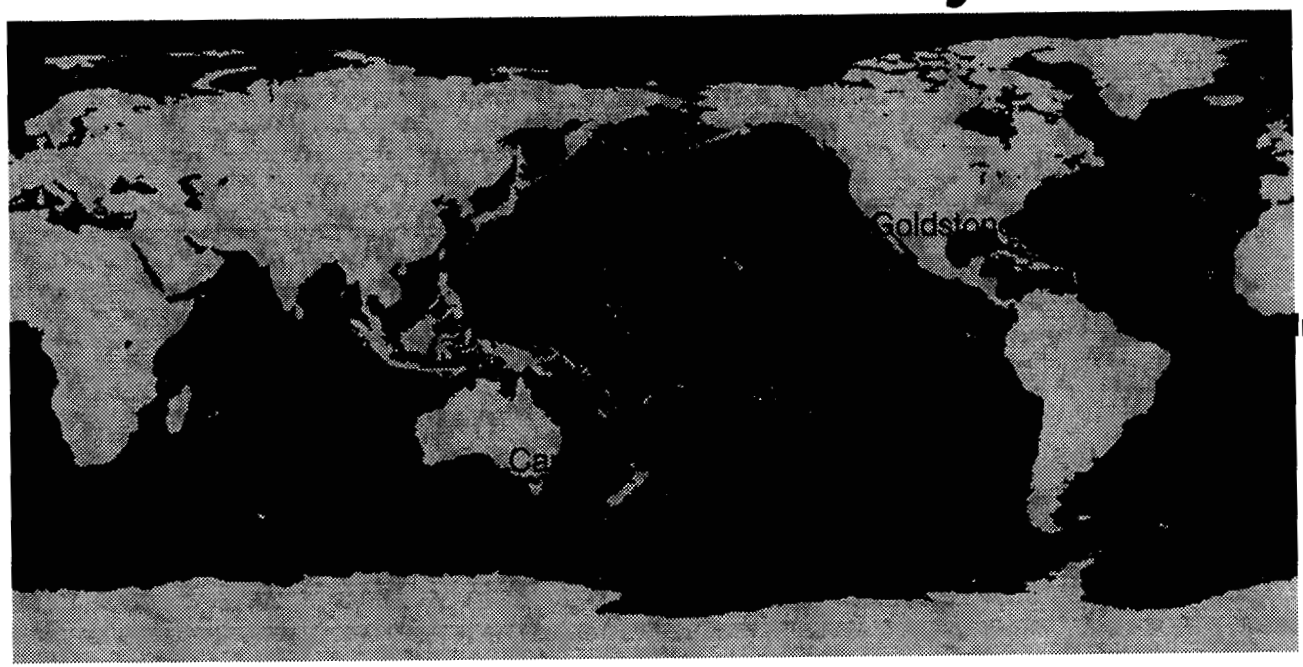


Hypothetical mission: Jovian Moon Explorer (JME)

Case 1:

Phase/Event	Description	Start	End	Requirements
Launch Activity	Launch and Early Ops Phase	12/21/2004	1/20/2005	Continuous (34BWG)
Cruise	Earth-Jupiter Cruise	1/20/2005	1/14/2008	2 8-hour tracks / week
Cruise	Jupiter Approach Tracking	1/14/2008	3/11/2008	1 8-hour track / day
Encounter Activity	JOI Tracking	3/11/2008	3/17/2008	Continuous (34BWG)
Cruise	Jupiter Orbit Reduction	3/17/2008	2/12/2009	3 8-hour tracks / week
Cruise	Jupiter Moon Approach Tracking	2/12/2009	3/11/2009	1 8-hour track / day
Encounter Activity	JMOI Tracking	3/11/2009	3/17/2009	Continuous (34BWG)
Prime Mission	JME Prime Mission	3/17/2009	4/16/2009	Continuous (34BWG)
Extended Mission	JME Extended Mission	4/16/2009	6/15/2009	Continuous (34BWG)
Cruise	JME Post-Extended Mission	6/15/2009	8/14/2009	Continuous (34BWG)

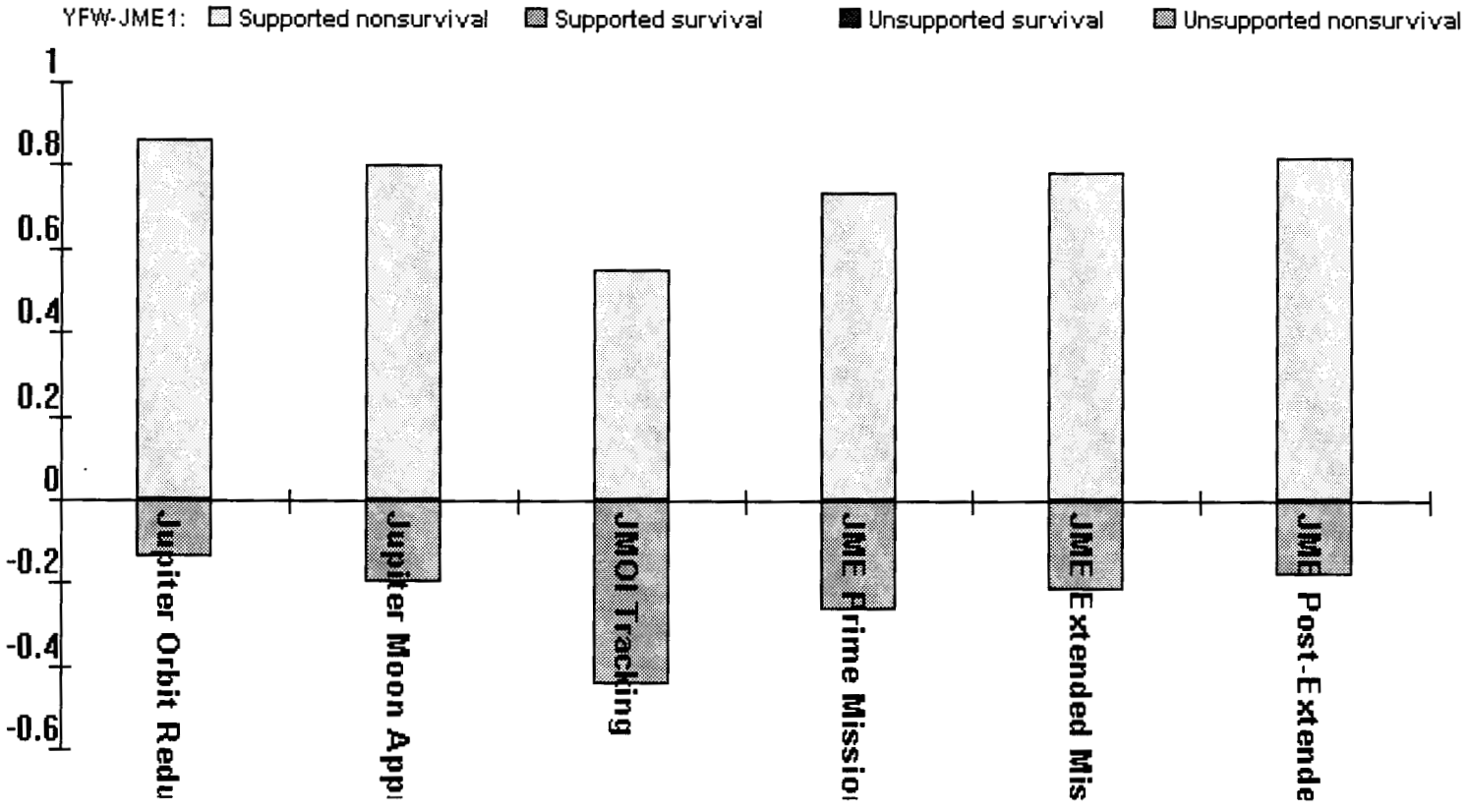
DSN Ground System



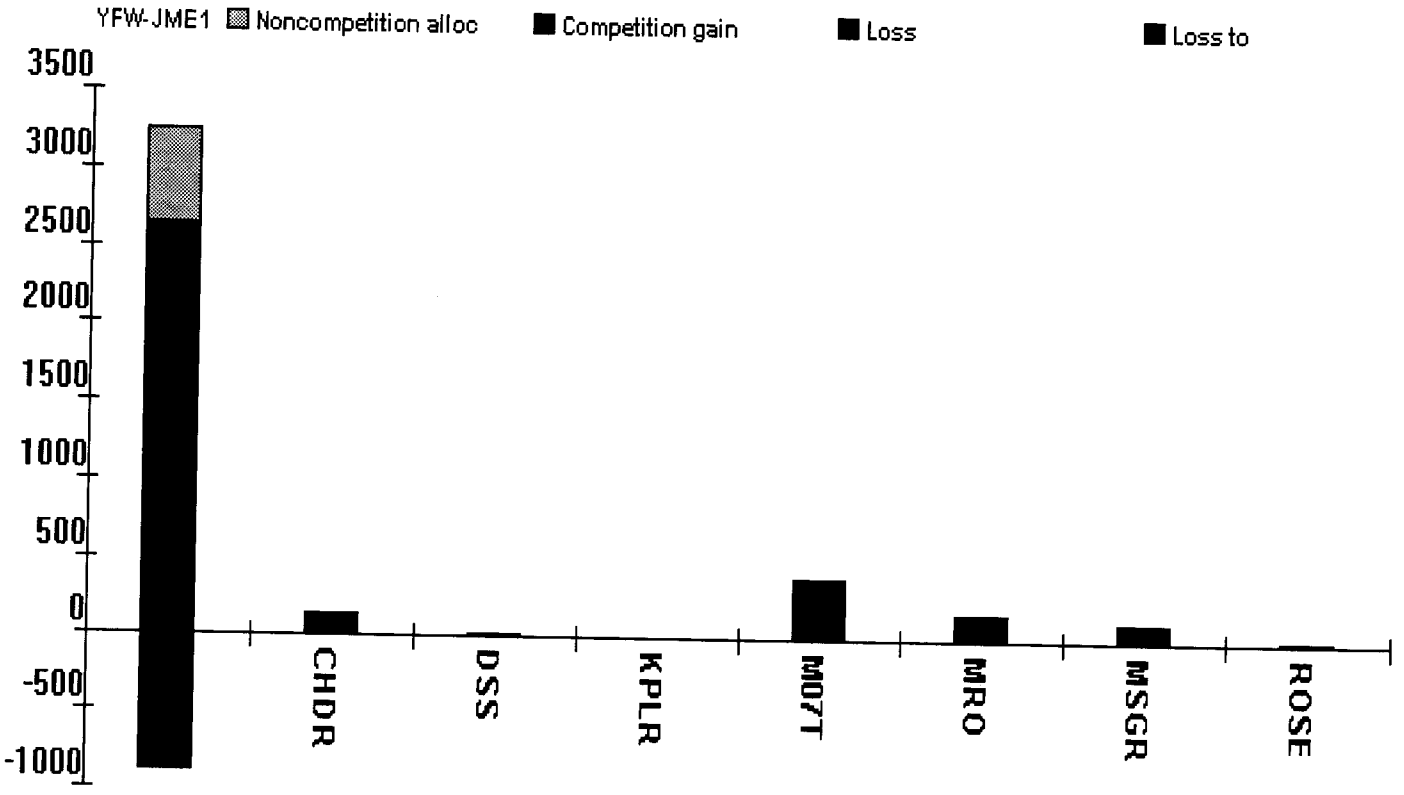
rid (70M,34M,26M)

- DSN antennas are located in Goldstone, CA, Madrid, Spain, and Canberra, Australia
- Each site has 70m, 34m, and 26m antennas available for supporting interplanetary space flight missions
- The JME study includes DSN support requirements from a total of 46 missions, including several at Mars

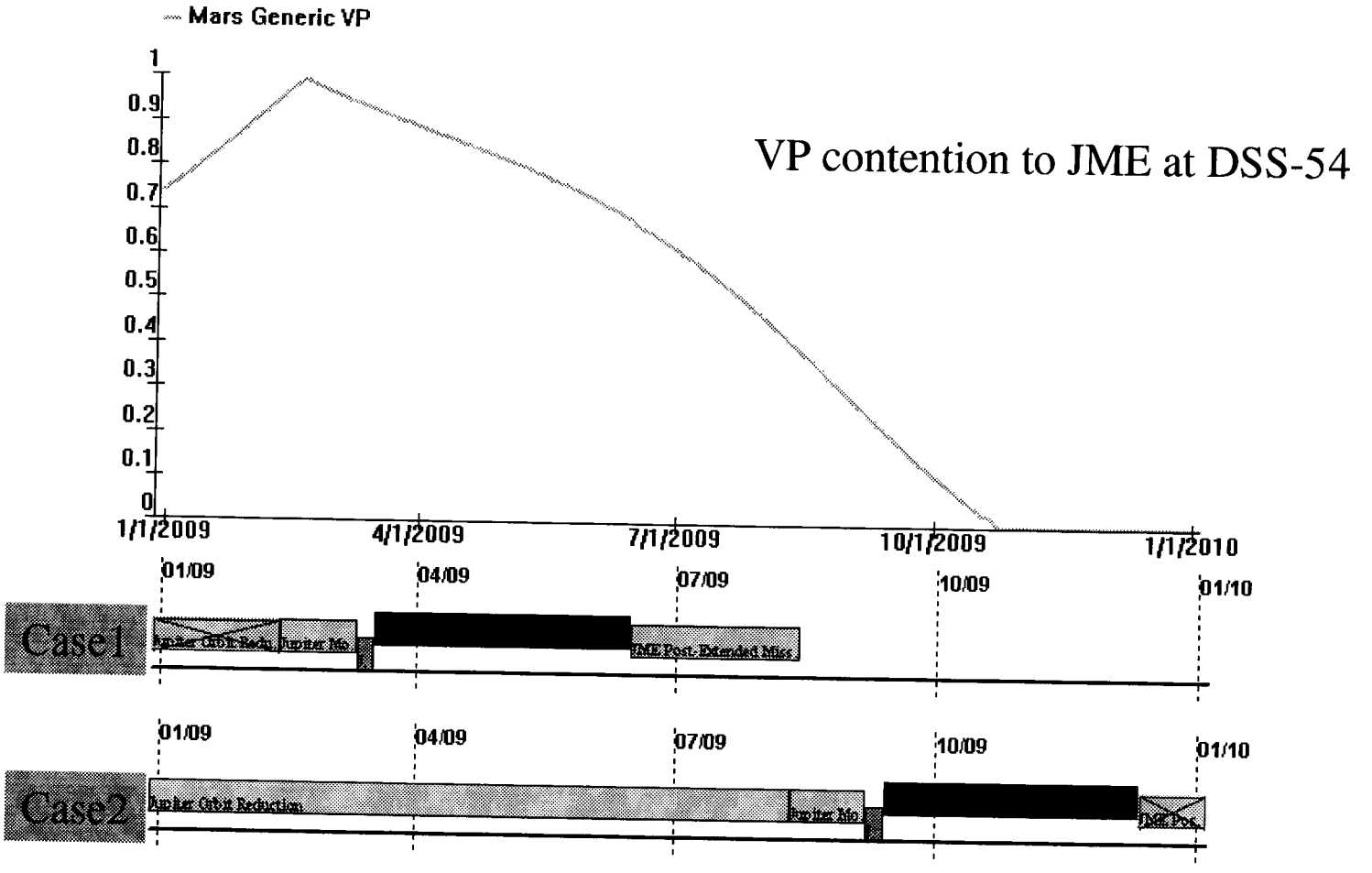
Supportability for Case 1



JME Competition for Case 1
(Year 2009)



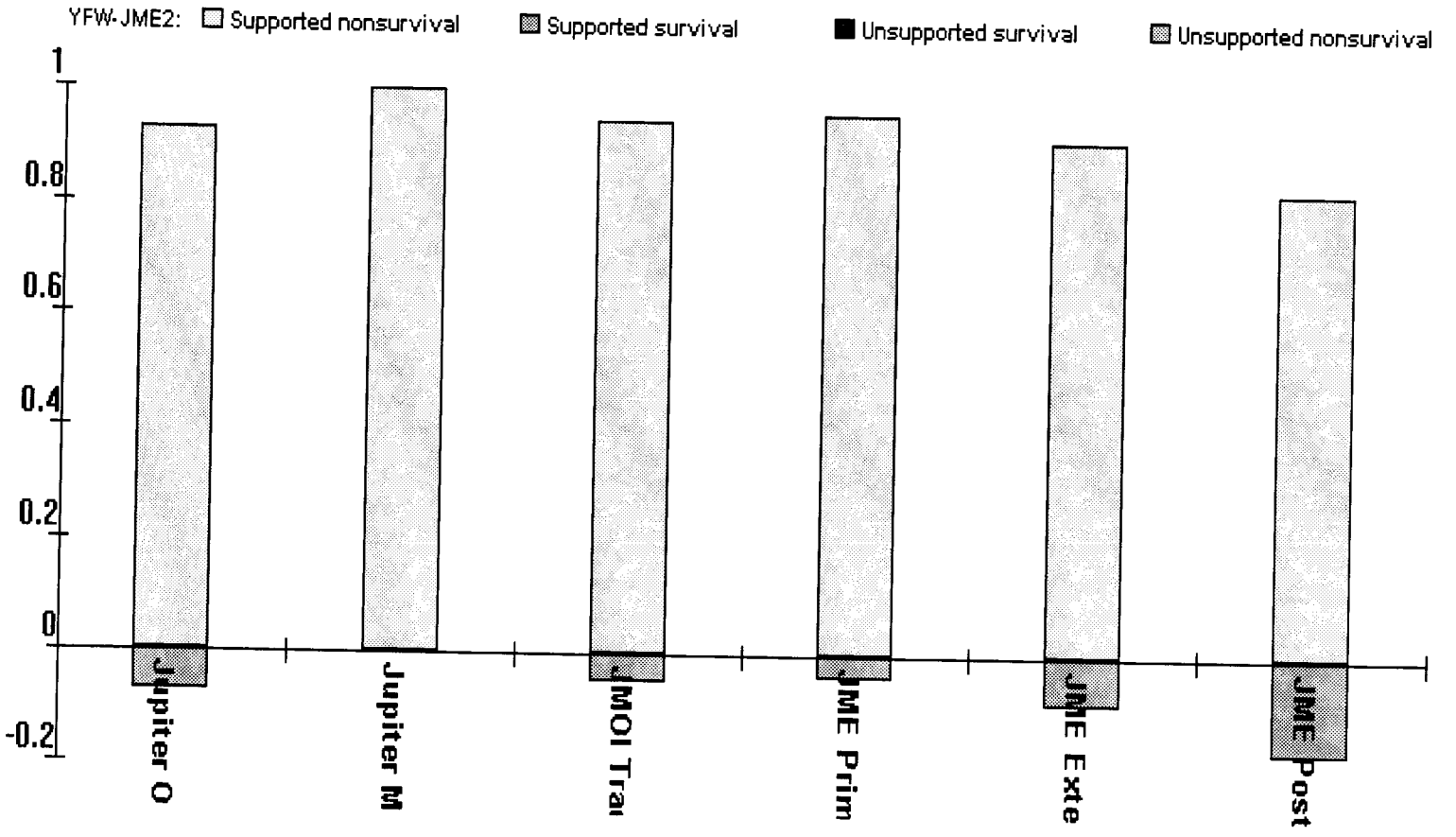
JME Viewperiod Overlap Example



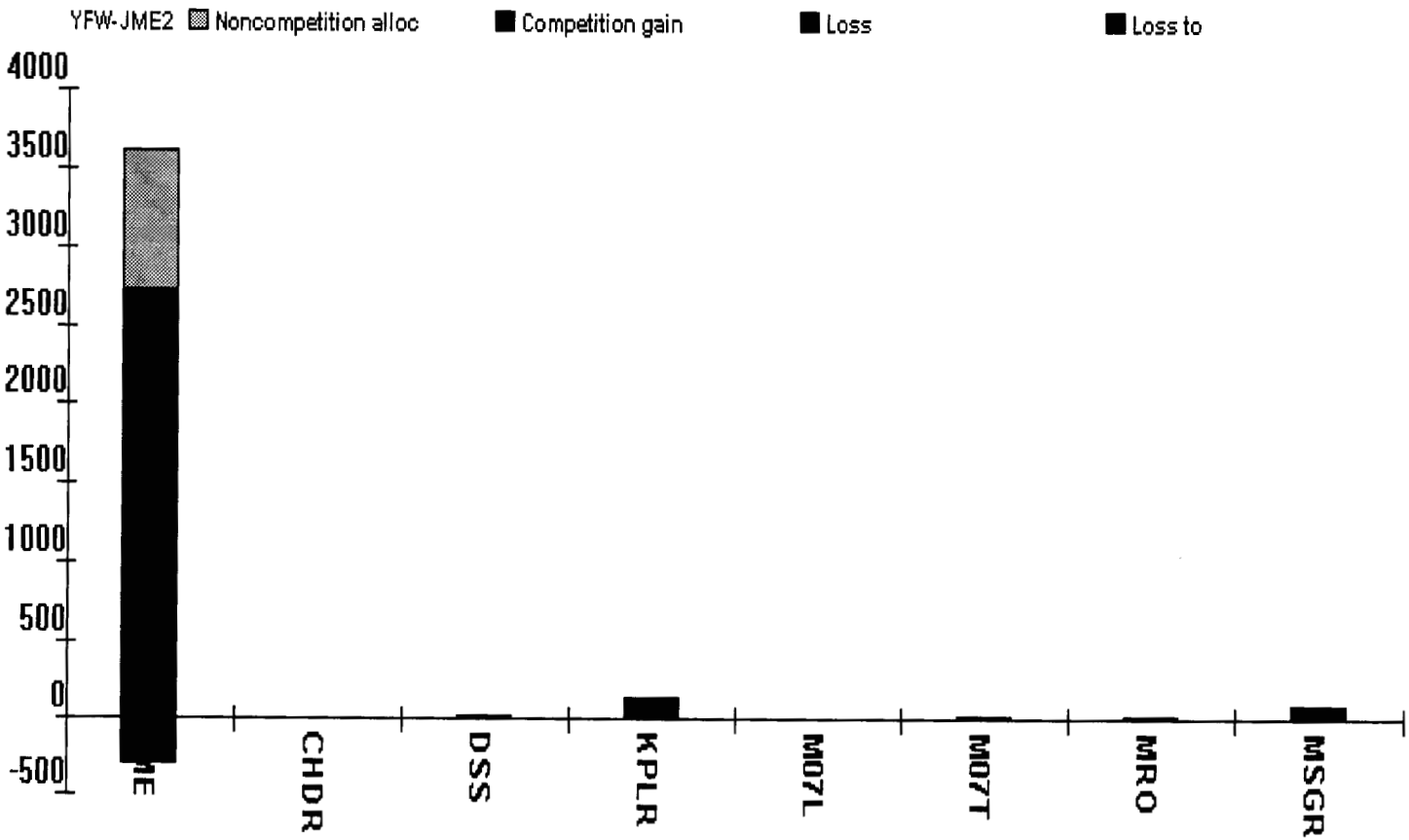
Case 2
Change Prime Mission Date

- From 3/17/09 to 9/13/09 by smaller engine burn to get captured into Jupiter system
- Investigate the impact on JME mission supportability due to a 6 month delay in order to overcome the competition with the set of missions exploring Mars
  - Approx. 20% to 40% loss of coverage during prime mission phases for case 1

Supportability for Case 2



JME Mission Contention for Case 2



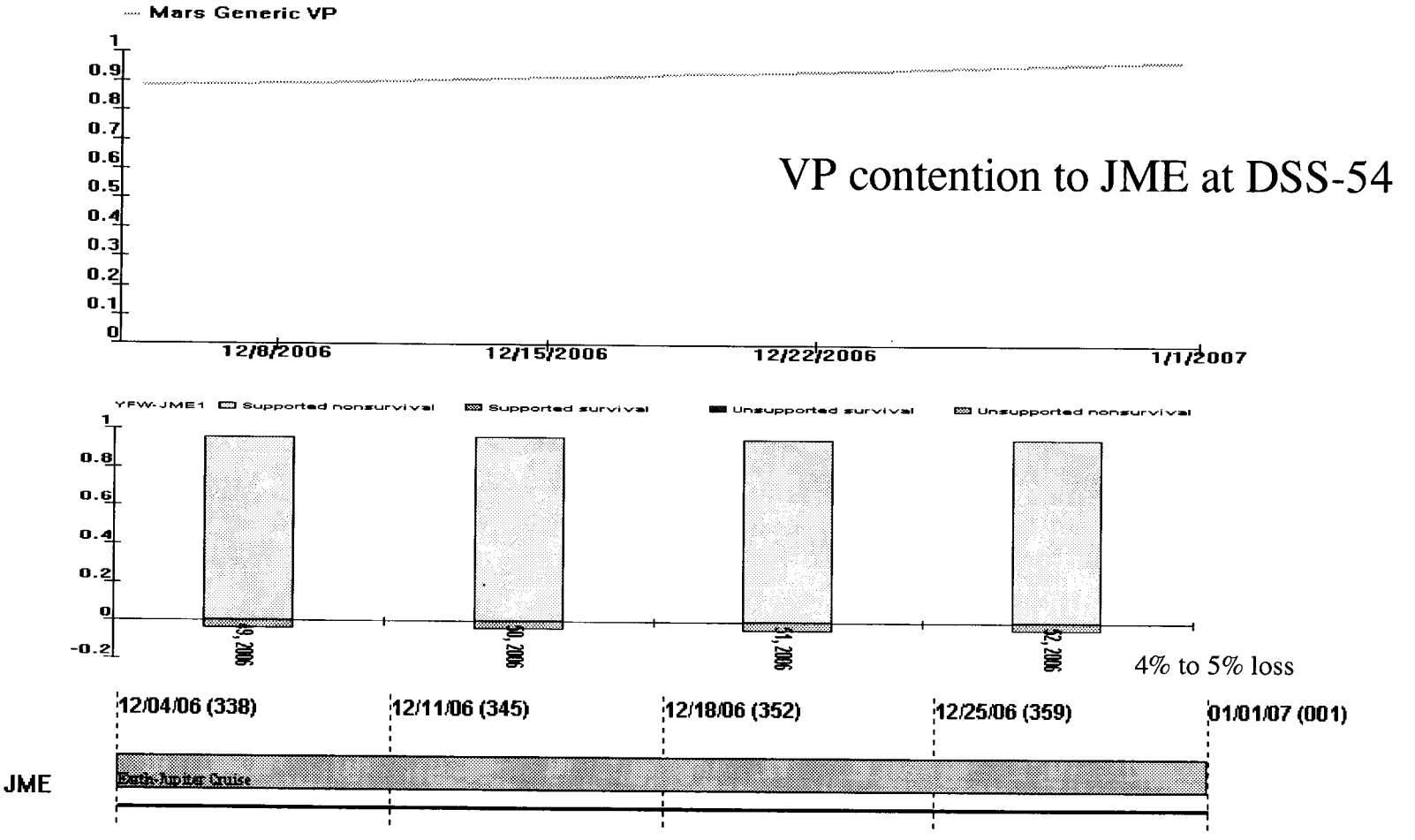
Comparison of JME Results for Case 1 and Case 2

- Result: significant improvement in spacecraft coverage by the DSN due to a 6 month arrival delay
  - Less than 10% loss for any of the prime phases
  - Minimal competition from Mars projects

Viewperiod Contention Limitations

- Is viewperiod contention an adequate proxy for mission contention and lost time?
- Does high viewperiod contention necessarily result in high mission contention?

High availability in high contention



*JME has a 4% t 5% loss during Earth-Jupiter Cruise due to low coverage requirements

Conclusion

- Viewperiod contention is not an adequate proxy for mission contention and lost time
- Contention is a combination of requirement, viewperiod, and constraints (e.g., antenna downtime).
- TIGRAS provides an integrated environment for all ground resource analysis needs
- Mission designer can use TIGRAS to perform early mission analysis to avoid costly redesign

Current Development

- Functionality:
  - More requirement types
  - Enhance scheduling intelligence
- Software:
  - Agent-based distributed multi-tier environment
  - Web services using XML/SOAP
  - Microsoft .NET 1.1 Framework
  - Current server development is called DRAGON (Distributed Remote Agents and Global brOkers Network)
  - Spacecraft trade/design/simulation and ground analysis any time, any where, multiple devices