Integration of Virtual Mission (VM) and Telecom Forecaster Predictor (TFP)

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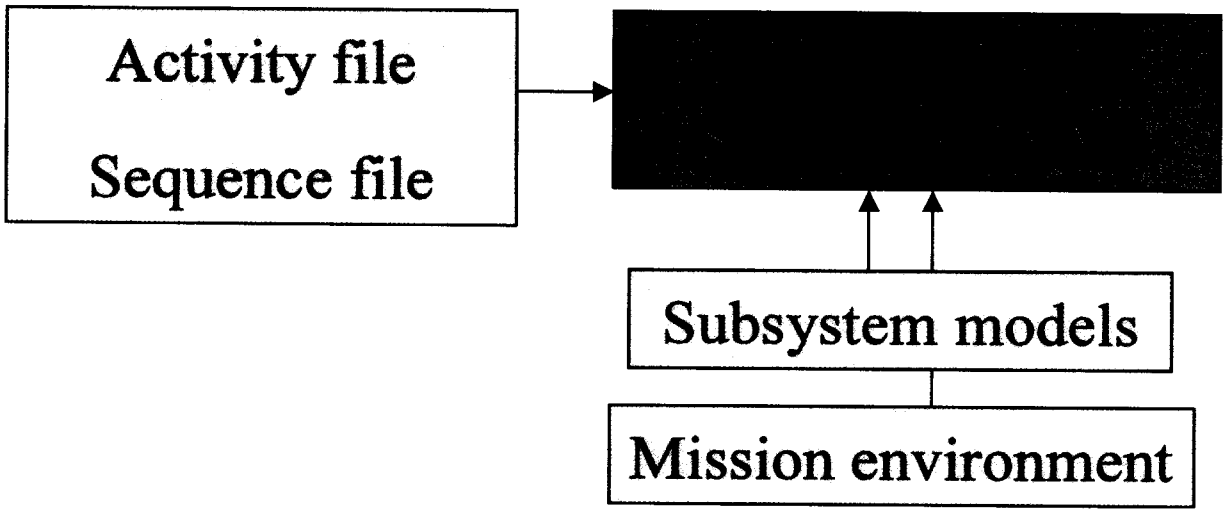
Agenda

- Virtual Mission (VM) Simulation
- Telecom Forecast Predictor (TFP) & Interface
- Integration of VM and Telecom Forecaster Predictor (TFP)
- Telecom Data File Processor
  - Parser, Value Validation and Selection
- Applications
  - Request Generator
  - Downlink Rate Analyzer
  - Mars Orbiter and Ground System Analysis
- Conclusion

Virtual Mission Simulation



- Activity file: define time line based subsystem operation
- Subsystem models: command and data handler, navigation, articulation, ACS, telecom, payloads.
- Environment model: science targets, solar system, star.
- Some model parameters are static, some are sensitive to operational condition.

Telecom Forecast Predictor (TFP) and Interface

- XML Description Files
  - DTD files.
  - XML files.
- TFP Interface
  - XML request file.
  - Apache web server.
  - CGI script.
  - Vmtfpbatch program.
- Flowchart
- Examples

XML Description Files

- DTD
  - Lists and describes all possible parameters.
  - Contains XML variable name.
  - Contains corresponding Matlab variable name.
  - Contains Matlab translation to desired format if other than a string.
  - DTD format files are tfp.dtd and a mission specific DTD file.

XML Description Files (cont.)

- XML
  - Contains rules concerning all parameters.
    - Possible values
    - Ranges
    - Default values
    - Dependencies
  - Dependencies have two types.
    - Special
      - Mainly for GUI display issues, handled by special Matlab code
    - Regular
      - Specified by dependency matrices, handled automatically by standard Matlab code
  - XML format files are dsn.xml and a mission specific .xml file.

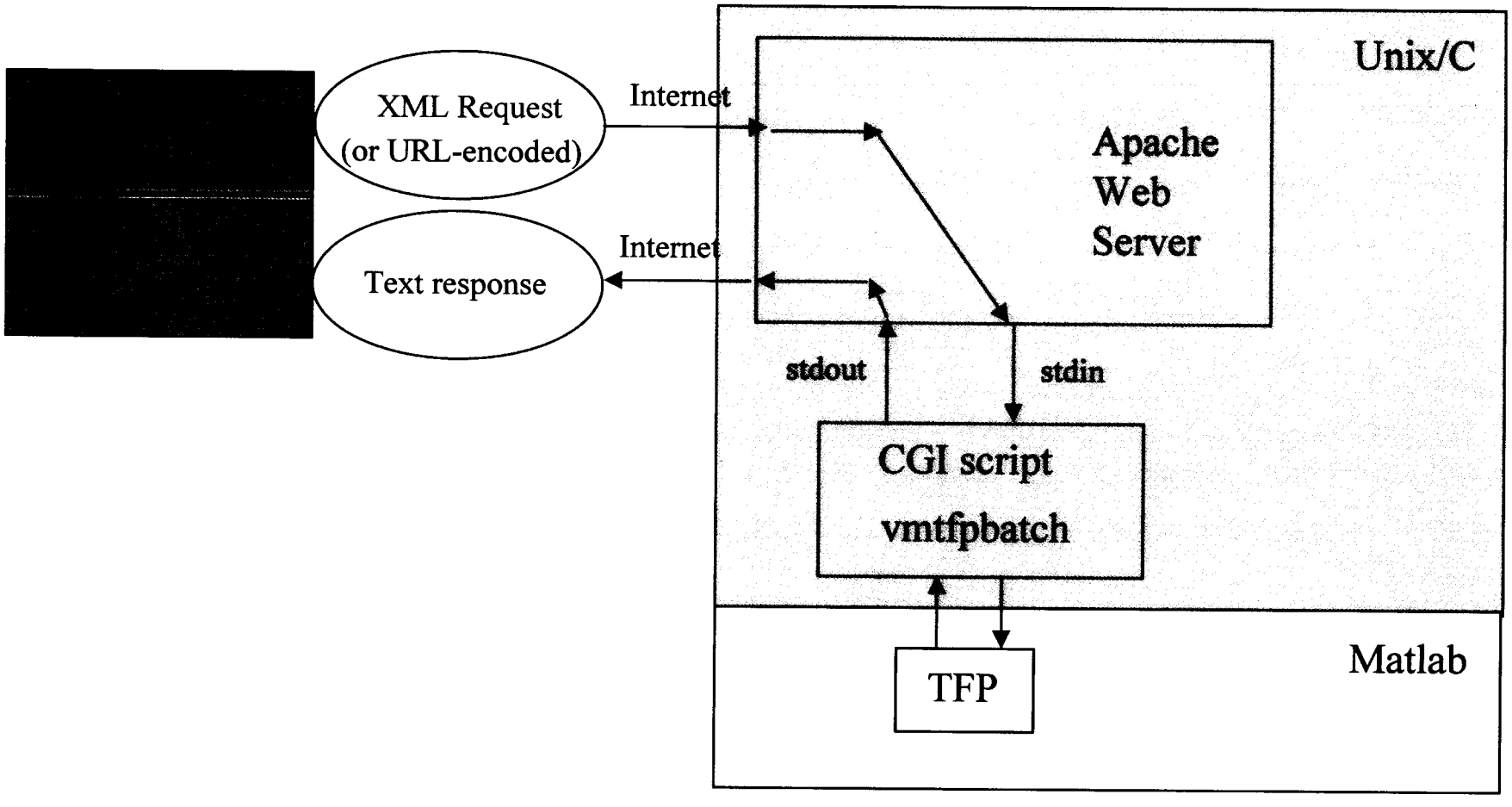
TFP Interface

- XML request file
  - Sent by Web browser or client.
  - Contains parameter names and desired values.
  - Based on XML description files to prevent illegal selections.
- Apache Web server
  - Receives XML request file and passes to CGI script "standard in".
  - Sends "standard out" results from CGI script back to Web client.

TFP Interface (cont.)

- CGI script
  - Runs the vmtfpbatch program.
  - Will also accept URL-encoded name-value pairs and convert to XML for vmtfpbatch.
- vmtfpbatch program
  - Translates input XML request file to Matlab .m file.
  - Opens Matlab engine.
  - Runs TFP using input file parameters.
  - Returns output on "standard out".
    - Data rate capacity and Eb/No.
    - Error messages if simulation fails.

TFP Flowchart



XML Description Files Examples

• DTD File

```
<?xml version="1.0" encoding="us-ascii"?>
<!-- DTD for Generic-specific TFP telecom modeling parameters -->
<!-- $Id: generic_donly.dtd,v 1.1.1.1 2002/05/31 16:05:15 tfpcm Exp $ -->
<!-- Draft 05/03/00 Ken Peters -->
<!-- Include here any elements specific to Generic -->
<!ELEMENT mission EMPTY>
<!ATTLIST mission
     xml_element CDATA   #FIXED  "mission"
     optional    (yes | no)  "no"
     value   CDATA   "generic"
>
<!ELEMENT generic (
     NAIF_ID?
) >
<!ELEMENT NAIF_ID (min_value*, max_value*, dependent_var*, value_list?)>
<!ATTLIST NAIF_ID
    xml_element CDATA   #FIXED  "generic/NAIF_ID"
    matlab_var  CDATA   #FIXED  "OR_SCID"
    numerize    CDATA   #FIXED  "if ~isempty(OR_SCID), OR_SCID = str2num(OR_SCID); end"
    optional    (yes | no)  "no"
    order   CDATA   #REQUIRED
    value   CDATA   #IMPLIED
    npoints CDATA   #IMPLIED
>
<!-- Include global tfp.dtd -->
<!ENTITY % tfp SYSTEM "../../com/scripts/tfp.dtd">
%tfp;
```

XML Description Files Examples

- XML File

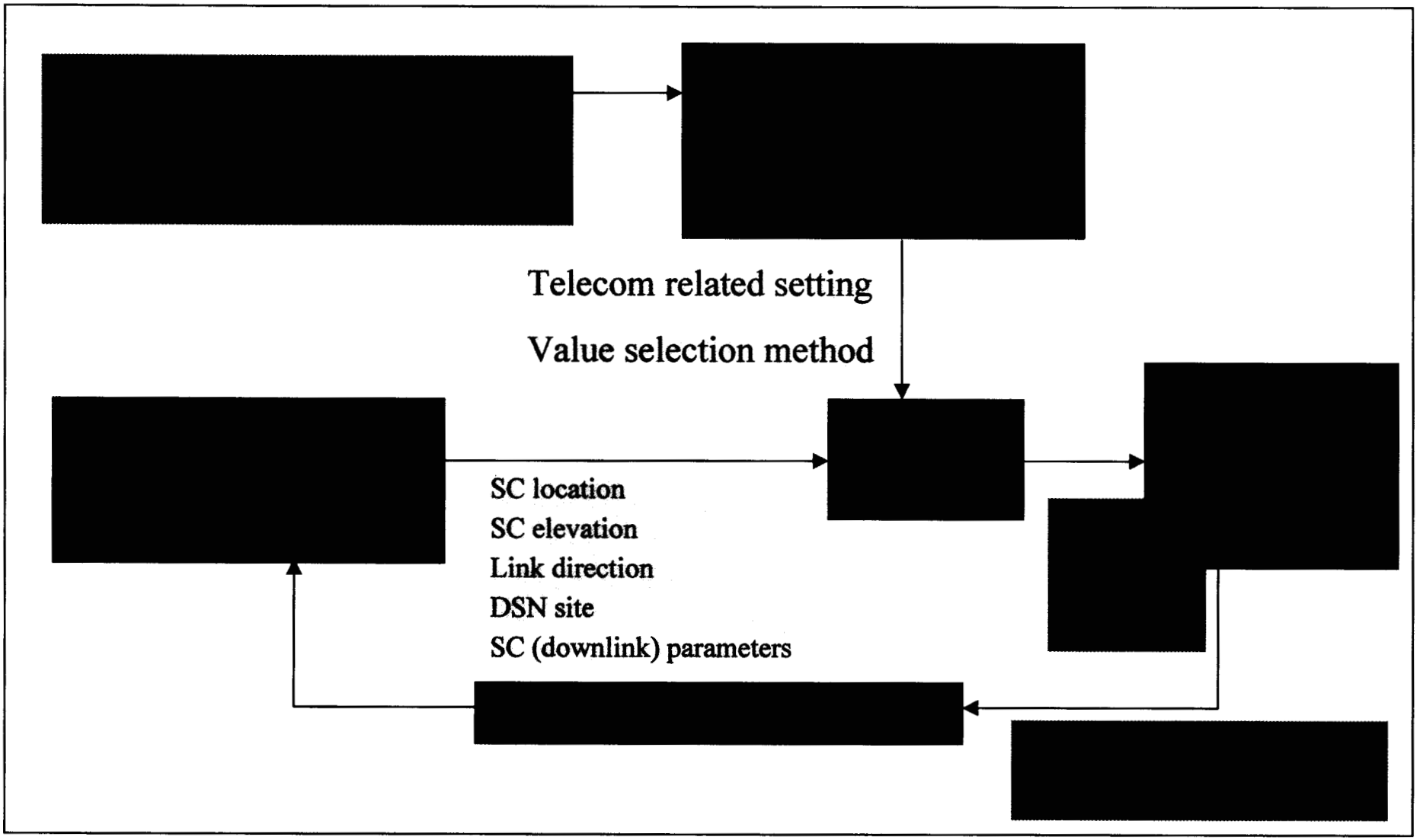
```
<?xml version="1.0" encoding="us-ascii"?>
<!-- Dependency specification file -->
<!-- $Id -->
<!DOCTYPE tfp SYSTEM "generic.dtd"
[
<!ENTITY DSNentries SYSTEM "./dsn.xml">
]>
<tfp><run>
     <simulation>
            <link_direction order="7" value="Down-Link">
                        <possible_value value="Up-Link"/>
                        <possible_value value="Down-Link"/>
                        <possible_value value="Two-Way"/>
                        <dependent_var value="dsn/site" follow="1"/>
            </link_direction>
            <model_name order="45" value=""/>
     </simulation>
            <dependency
               independent="simulation/link_direction"
               dependent="dsn/site">
               <matrix prereq_var="simulation/analysis_mode" prereq_value="Predict">
               <!--    A  C  M  G  CC  CM  CG  MC  MM  MG  GC  GM  GG  -->
               <row>   0  1  1  1   0   0   0   0   0   0   0   0   0  </row> <!-- Up -->
               <row>   0  1  1  1   0   0   0   0   0   0   0   0   0  </row> <!-- Down -->
               <row>   0  0  0  0   1   1   1   1   1   1   1   1   1  </row> <!-- Two-way -->
               </matrix>
            </dependency>
...
```

XML Request File Example

- XML Request File

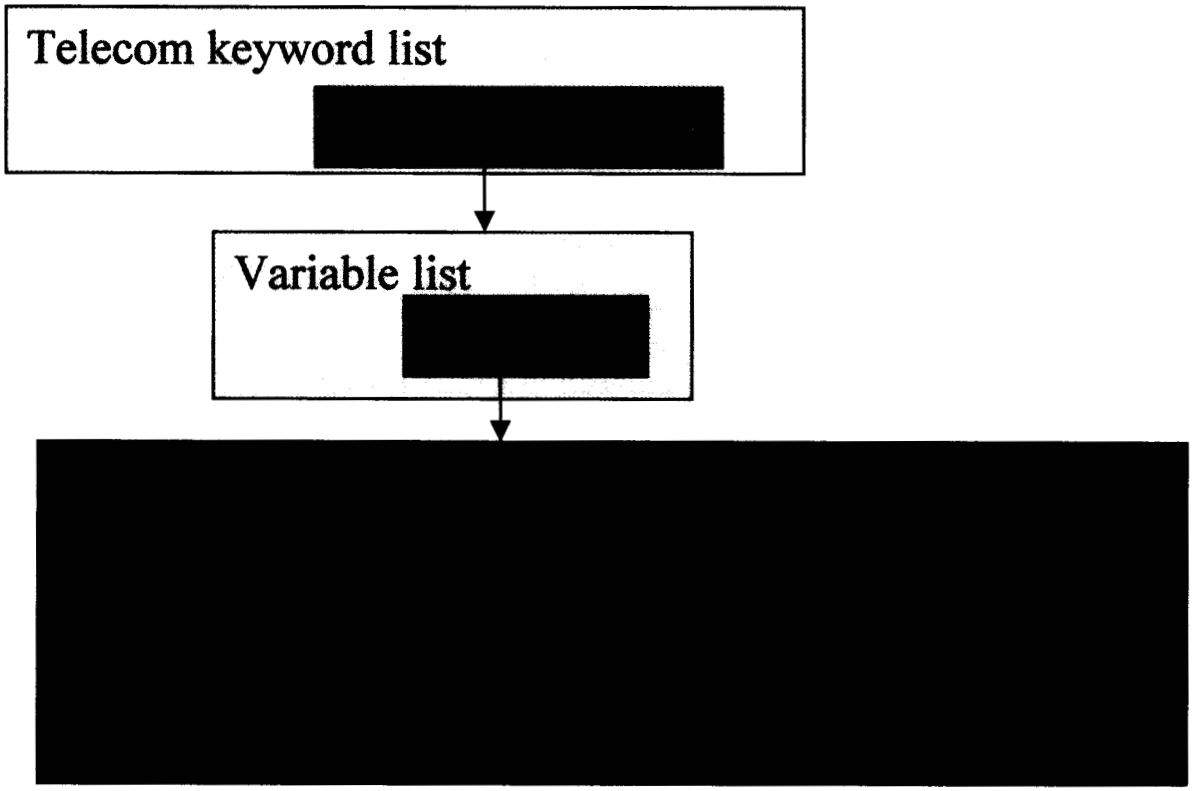
```
<?xml version="1.0" encoding="us-ascii"?>
<!DOCTYPE tfp SYSTEM "generic/scripts/generic.dtd">
<tfp><run>
        <simulation>
            <analysis_mode value="Predict"/>
            <link_direction value="Down-Link"/>
            <model_name value=""/>
        </simulation>
        <time>
            <start value=""/>
            <end value=""/>
            <unit value="Minutes"/>
            <plot_unit value="UTC"/>
            <nsteps value="100"/>
            <step value=""/>
        </time>
        <downlink>
            <tlm_datarate value="1900000"/>
            <coding value="Reed Solomon (255,223) concatenated with C.E. (7,1/2)"/>
            <carrier_tracking value="Residual"/>
            <subcarrier value="Squarewave"/>
            <tlm_modindex value="80"/>
            <tlm_range_modindex value="0"/>
            <differential_ranging value="Off"/>
        </downlink>
</run></tfp>
```

Integration of VM and TFP
(for Mars Orbiter Case)



Telecom Data File Parser

- XML parser
- Telecom variables are stored in a tree-like structure



Telecom Variable Value Validation

Which variable is validated?

- All dependent variables of any variable and "followed" variables are validated.

Value validation is based on rules listed in

- All dependency matrix
- Special case not expressible by matrix

Valid Value Selection Method

Three valid value selection methods are provided

- All selection – Combination of all possible valid values are traversed.
- Single selection – the value of all variables are fixed except the valid values of one variable are traversed.
- Fixed selection – the value of all variable are uniquely specified and validated.

Value Selection Algorithm

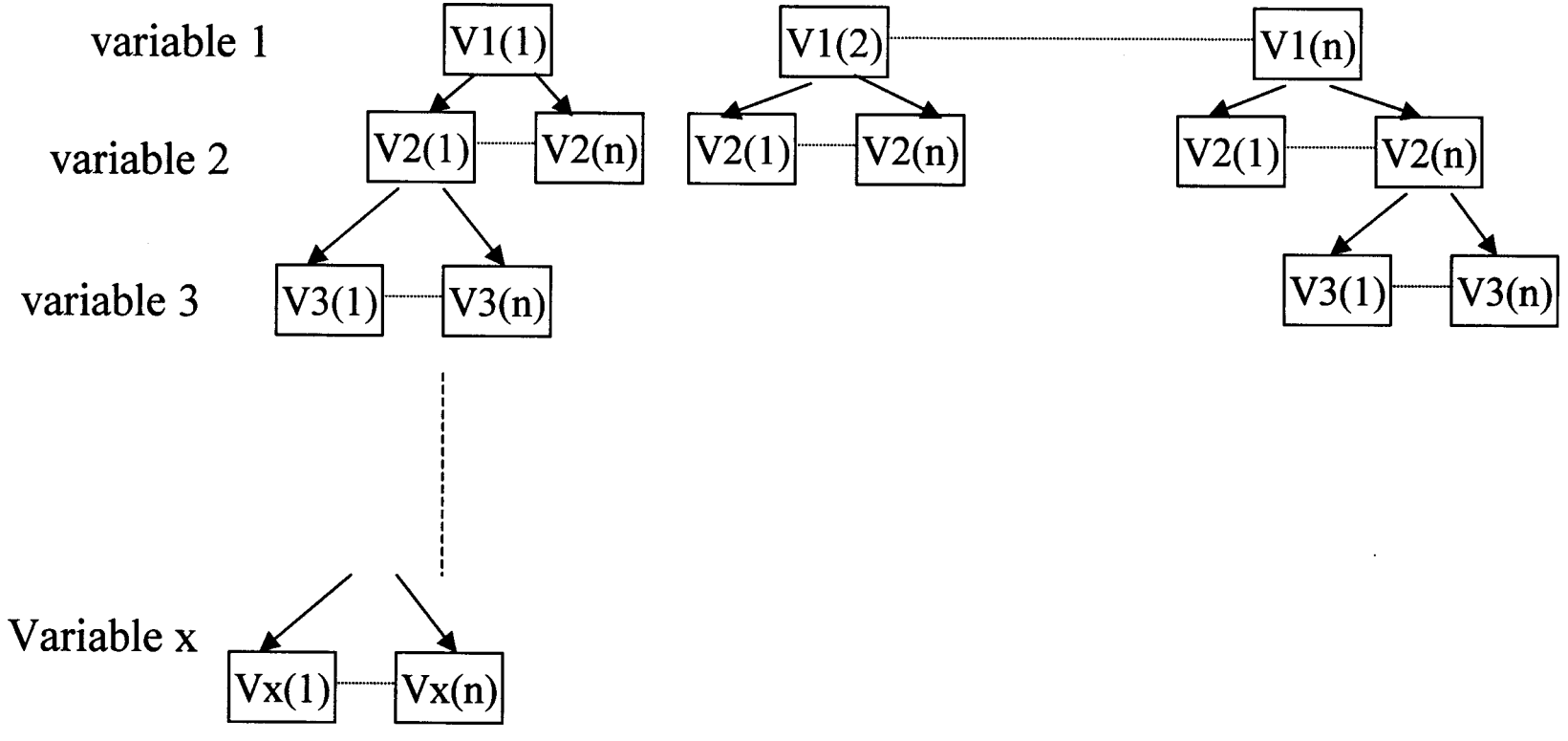
- Efficient algorithm for" all selection" method
  - ✓ Classify all variables into two groups:

    group 1: variable which value depends on other values

    group 2: not variables of group 1.
  - ✓ arrange the valid values of group 1 variables into a tree structure based on all dependency.
  - ✓ traverse the valid values of group 1 variables from the the bottom of the tree
  - ✓ Compute value combination of group 2 variables
  - ✓ Combine validated data set of group 1 and group 2.

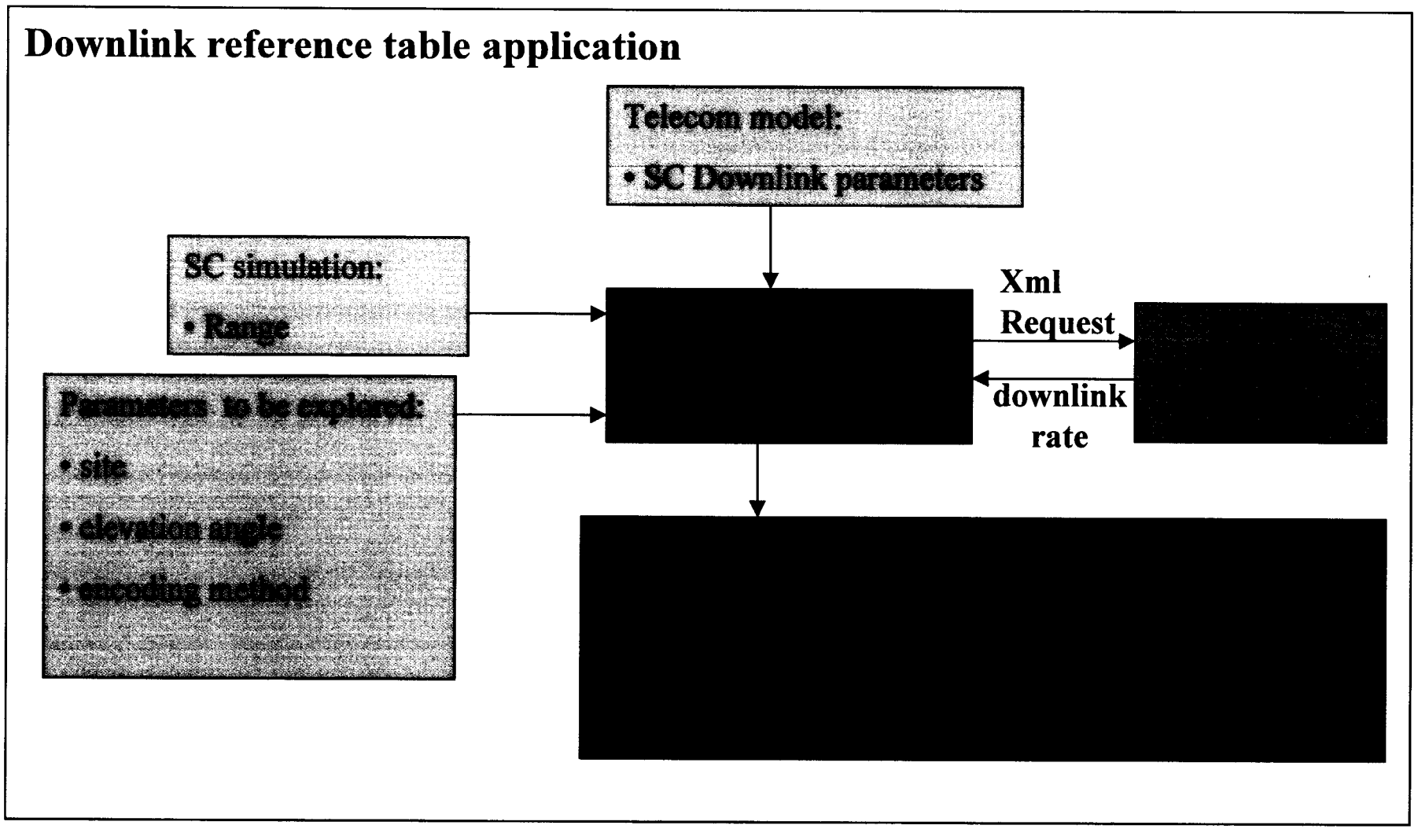
Value Selection Algorithm (cont.)

- Valid value tree of group 1 variables:



Application on Telecom Request Generator

Downlink reference table application



Telecom Model

```
#TELECOM MODEL
TELECOM = "gimabel_related"
{
    SIMULATION
    {
        LINK_DIRECTION = "Down-Link"        # Down-Link, Up-Link, Two-Way,
    }
    GENERIC_DOWNLINK
    {
        FREQ_BAND = "Manual"                          # Manual, S, X, Ka
        DOWNLINK_FREQUENCY = 8420
        FREQ_CHANNEL = 14

        SC_XMT_POWER  = 44                            # 0 - Inf
        SC_XMT_CIRCUIT_LOSS = -1                      # (-Inf) - 0
        SC_XMT_ANTENNA_GAIN_MODE = "Calculated"       # Calculated, Manual
        SC_XMT_ANTENNA_GAIN = 50                      # 0.0001 - Inf, if gain_mode == "Calculated"
        SC_XMT_ANTENNA_SIZE =  4                      # 0.0001 - Inf  if gain_mode == "manual"

        SUBCARRIER_FREQ = 0                           # 0 - Inf, default
        SC_XMT_ANTENNA_EFFICIENCY = 0.45              # 0.45, 0.70, default, if gain_mode == "manual"
        SC_XMT_HALF_POWER_BEAMWIDTH = 0.5             # 0 - Inf, default
        SC_XMT_AXIAL_RATIO = 3                        # 0 - Inf, default

        SC_XMT_OTHER_LOSS = 0                         # 0 - Inf
        SC_XMT_OTHER_LOSS_VARIANCE = 0                # 0 - Inf, default

        SC_XMT_ANTENNA_PATTERN_FILE = "zerpatt.dat"         # if no pattern, use default
        SC_XMT_ANTENNA_PATTERN_DIMENSION = "One"            # "One", "Two"
        SC_XMT_ANTENNA_PATTERN_HANDED = "Right-Handed"      # "Right-Handed", "Left-Handed"
        SC_XMT_ANTENNA_PATTERN_CLOCK_DIR = "Column"         # "Row", "Column"
        SC_XMT_ANTENNA_PATTERN_CLOCK_RANGE = "[-180, 180]" # [-180, 180], [0, 360]

        DOWNLINK_CNR_THRESHOLD = 75                         # (db), for different mission
        DOWNLINK_PR_NO_THRESHOLD = -10                      # (db-HZ)
    }
}
```

Downlink Rate Reference Table

Reference distance: 299093049.149640

Turbo, rate 1/2, block length 8920

	Goldstone(DSS 25)	Canberra(DSS 34)	Madrid(DSS 54)
10.0	1225403.303900	962670.987500	1084643.847100
15.0	1488999.813800	1148776.722200	1340928.938100
20.0	1660986.379000	1267015.439700	1515922.090600
25.0	1776352.314400	1348375.132600	1641321.983100
30.0	1856347.863600	1407326.768900	1733998.202300
35.0	1913757.369200	1451531.485700	1803996.257800
40.0	1956181.292400	1485420.992900	1857681.337200
45.0	1988172.665200	1511732.602500	1899242.992900
50.0	2012522.277500	1532243.582000	1931513.242800
55.0	2030995.643600	1548153.011400	1956446.632400
60.0	2044748.357200	1560293.744700	1975415.015000
65.0	2054560.800200	1569256.333500	1989393.782600
70.0	2060972.757300	1575464.510200	1999081.772400
75.0	2064362.269700	1579222.597500	2004979.436700
80.0	2064992.804600	1580745.856300	2007440.084500
85.0	2063041.808800	1580179.948400	2006703.271500
90.0	2058617.754900	1577613.055600	2002915.928800

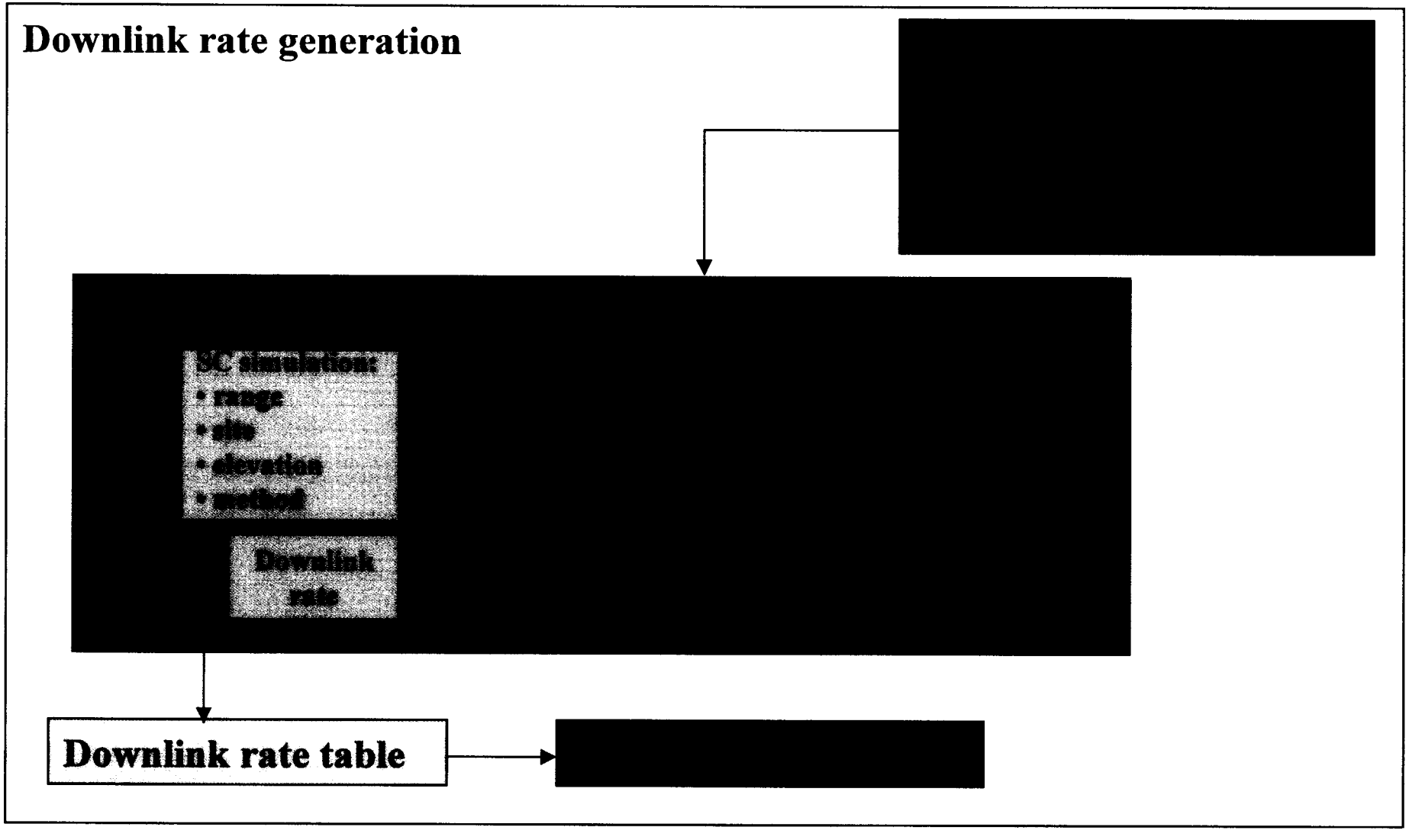
Reed Solomon Only (255, 223)

	Goldstone(DSS 25)	Canberra(DSS 34)	Madrid(DSS 54)
10.0	355450.432500	279240.163400	314620.601500
15.0	431911.376500	333223.503900	388960.736000
20.0	481799.196100	367520.786400	439720.670700
25.0	515263.176100	391120.639600	476095.181700
30.0	538467.334600	408220.629900	502977.598400
35.0	555120.002000	421043.009000	523281.802700
40.0	567425.829600	430873.274600	538854.132800
45.0	576705.507000	438505.433700	550909.844100
50.0	583768.553200	444455.015000	560270.414800
55.0	589127.087800	449069.833300	567502.796300
60.0	593116.311600	452591.473000	573004.919400
65.0	595962.588500	455191.234300	577059.714200
70.0	597822.492800	456992.028400	579869.891200
75.0	598805.682300	458082.129700	581580.615600
80.0	598988.580400	458523.978500	582294.371100
85.0	598422.658700	458359.826700	582080.645100
90.0	597139.381700	457615.252900	580982.057700

XML Request

```
<?xml version="1.0" encoding="us-ascii"?>
<!DOCTYPE tfp SYSTEM "generic/scripts/generic.dtd">
<tfp><run>
    <simulation>
        <analysis_mode value="Predict"/>
        <link_direction value="Down-Link"/>
        <model_name value=""/>
    </simulation>
    <time>
        <start value=""/>
        <end value=""/>
        <unit value="Minutes"/>
        <plot_unit value="UTC"/>
        <nsteps value="100"/>
        <step value=""/>
    </time>
    <range_elevation>
        <range value="299093049.149640"/>
        <elevation value="90.000000"/>
    </range_elevation>
    <dsn>
        <site value="Madrid"/>
        <xmt_antenna value=""/>
        <rcv_antenna value="DSS 54"/>
        <rf_band value="X"/>
        <uplink_rf_band value=""/>
        <downlink_rf_band value="X"/>
        <array_file value=""/>
        <low_noise_amp value="LNA-1"/>
        <diplex value="Bypass Diplex"/>
        <transmit_power value=""/>
        <atmosphere_model value="CD90: 90%"/>
        <phase_lock_bandwidth value="5 Hz"/>
        <elevation_mask value="In View"/>
        <elevation_value value=" "/>
    </dsn>
    <spacecraft name = "Generic">
        <operational_mode value="Nominal"/>
        <mission_phase value="General"/>
        <configuration value="Config-A"/>
        <pointing_mode value="EarthPointed"/>
        <sc_antenna value="ScAntenna"/>
        <boresight_offset value="0">
        </boresight_offset>
    </spacecraft>
    <uplink>
        <cmd_datarate value="0"/>
        <cmd_modindex value="0"/>
        <cmd_range_modindex value="0"/>
    </uplink>
    <downlink>
        <tlm_datarate value="1900000"/>
        <coding value="Reed Solomon (255,223) concatenated with C.E. (7,1/2)"/>
        <carrier_tracking value="Residual"/>
        <subcarrier value="Squarewave"/>
        <tlm_modindex value="80"/>
        <tlm_range_modindex value="0"/>
        <differential_ranging value="Off"/>
    </downlink>
    <generic>
        <NAIF_ID value="499"/>
    </generic>
    <generic_downlink>
        <downlink_freq_band value="Manual"/>
        <downlink_frequency value="8420"/>
        <downlink_freq_channel value="14"/>
        <downlink_subcarrier_freq value="0"/>
        <sc_xmt_power value="44.000000"/>
        <sc_xmt_circuit_loss value="-1.000000"/>
        <sc_xmt_antenna_gain_mode value="Calculated"/>
        <sc_xmt_antenna_gain value="50.000000"/>
        <sc_xmt_antenna_size value="4"/>
        <sc_xmt_antenna_efficiency value="0.45"/>
        <sc_xmt_half_power_beamwidth value="0.5"/>
        <sc_xmt_axial_ratio value="3"/>
        <sc_xmt_other_loss value="-4.065000"/>
        <sc_xmt_other_loss_variance value="0"/>
        <sc_xmt_antenna_pattern_file value="zeropatt.dat"/>
        <sc_xmt_antenna_pattern_dimension value="One"/>
        <sc_xmt_antenna_pattern_handed value="Right-Handed"/>
        <sc_xmt_antenna_pattern_cone_dir value="Row"/>
        <sc_xmt_antenna_pattern_clock_dir value="Column"/>
        <sc_xmt_antenna_pattern_clock_range value="[-180, 180]"/>
        <downlink_CNR_threshold value="12"/>
        <downlink_Pr_No_threshold value="-10"/>
    </generic_downlink>
</run></tfp>
```

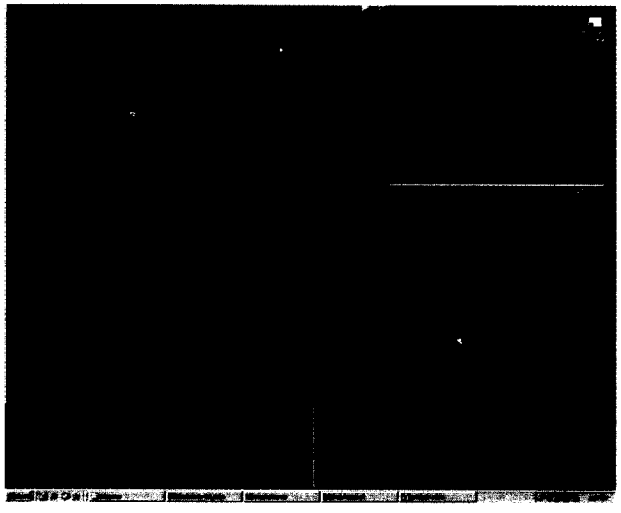
Application for Analyzing Downlink Rate

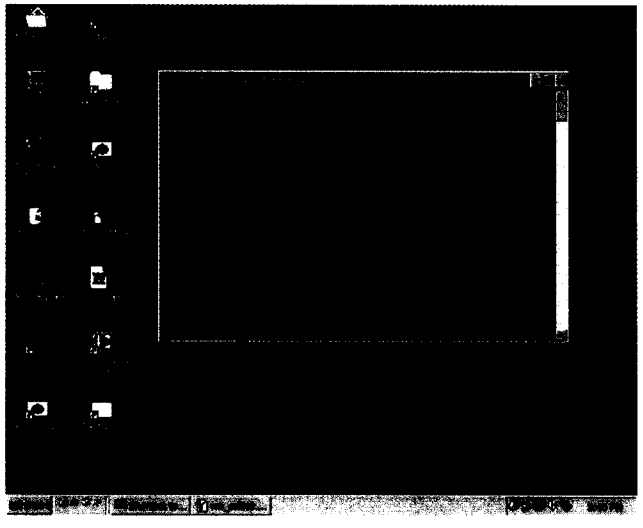


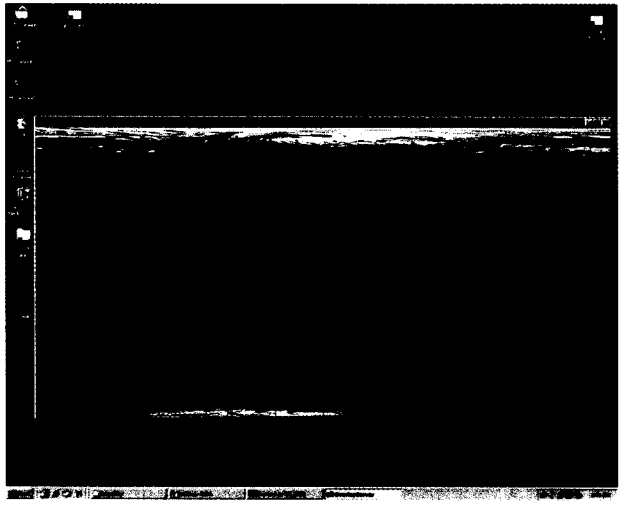
Downlink Rate Table

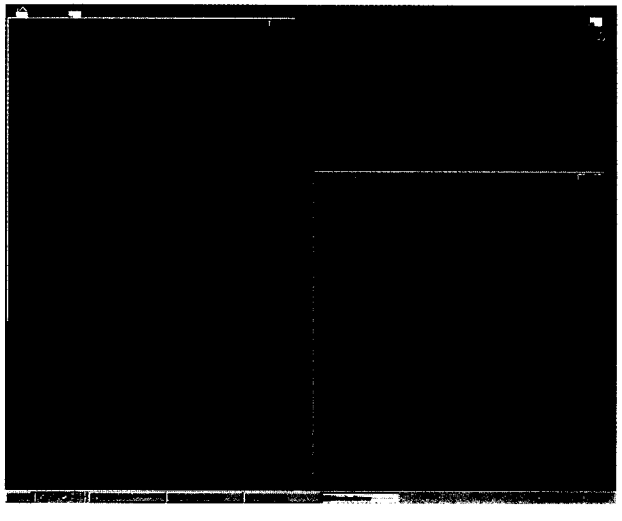
Number of Orbit: 4000
Number of Rates: 2
Rate 1: Turbo 1/2
Rate 2: Reed Solomon only
Orbit = 0 Period = (1/ 1: 0:47 - 2: 6)
1 D (363298895.72) E (13.62) T (Canberra) A (DSS 34) R (1, 743907.339395) (2, 215783.803267)
2 D (363295362.80) E (11.87) T (Canberra) A (DSS 34) R (1, 699613.591137) (2, 202935.599003)
3 D (363291794.00) E (10.30) T (Canberra) A (DSS 34) R (1, 660081.897023) (2, 191468.714829)
4 D (363288581.26) E (10.00) T (Canberra) A (DSS 34) R (1, 652509.785333) (2, 189272.286630)
5 D (363286008.72) E (10.00) T (Canberra) A (DSS 34) R (1, 652519.026613) (2, 189274.967231)
6 D (363284166.57) E (10.00) T (Canberra) A (DSS 34) R (1, 652525.644260) (2, 189276.886799)
7 D (363282923.71) E (10.00) T (Canberra) A (DSS 34) R (1, 652530.109104) (2, 189278.181908)
8 D (363281967.42) E (10.00) T (Canberra) A (DSS 34) R (1, 652533.544492) (2, 189279.178405)
Orbit = 1 Period = (1/ 1: 2:39 - 3:58)
1 D (363273255.80) E (16.19) T (Canberra) A (DSS 34) R (1, 797755.901102) (2, 231403.554311)
2 D (363269719.71) E (18.17) T (Canberra) A (DSS 34) R (1, 829625.117610) (2, 240647.798030)
3 D (363266147.36) E (20.21) T (Canberra) A (DSS 34) R (1, 861249.362198) (2, 249820.983206)
4 D (363262931.19) E (22.29) T (Canberra) A (DSS 34) R (1, 884145.476329) (2, 256462.415998)
5 D (363260355.79) E (24.39) T (Canberra) A (DSS 34) R (1, 907328.394947) (2, 263187.041628)
6 D (363258511.61) E (26.51) T (Canberra) A (DSS 34) R (1, 926141.463909) (2, 268644.113174)
7 D (363257267.59) E (28.64) T (Canberra) A (DSS 34) R (1, 943203.663377) (2, 273593.313293)
8 D (363256310.77) E (30.79) T (Canberra) A (DSS 34) R (1, 958778.254315) (2, 278111.005604)
:
:
Orbit = 3999 Period = (11/ 9:22:38 - 23:33)
1 D (166523580.74) E (64.17) T (Canberra) A (DSS 34) R (1, 5057583.280254) (2, 1467043.673333)
2 D (166513999.52) E (65.78) T (Canberra) A (DSS 34) R (1, 5066090.836868) (2, 1469511.444273)
3 D (166505380.99) E (67.44) T (Canberra) A (DSS 34) R (1, 5073254.866706) (2, 1471589.500892)
4 D (166497846.26) E (69.14) T (Canberra) A (DSS 34) R (1, 5080528.562947) (2, 1473699.368238)
5 D (166491188.11) E (70.88) T (Canberra) A (DSS 34) R (1, 5086520.979225) (2, 1475437.577127)
6 D (166484933.70) E (72.66) T (Canberra) A (DSS 34) R (1, 5091216.537521) (2, 1476799.608874)

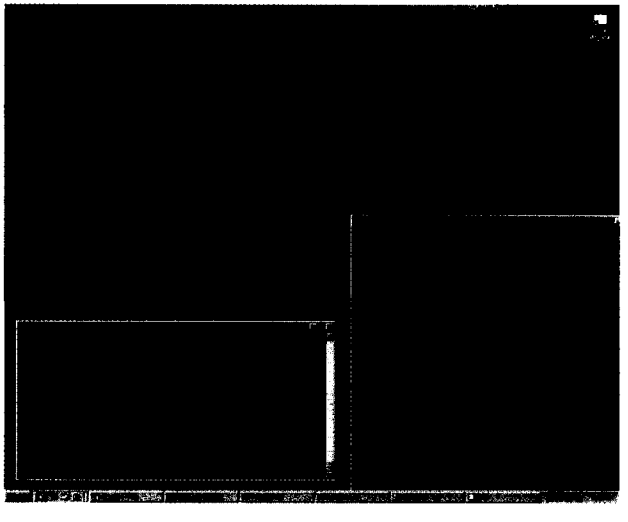
Application for Mars Orbiter











Conclusion

- XML is effective as interface format.
- The telecom performance data can be dynamically updated by interacting with remote TFP as VM simulation proceeds.
- Set foundation for other users to remotely access TFP software for telecom calculations, rather than developing their own.
- Set foundation for building interface between VM and other subsystem analysis tool to resolve updating the dynamic subsystem model parameters.
- The accuracy and reliability of VM simulation is enhanced.