

Evaluation Criteria for the MORSE Simulation Environment

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CMU-RI-TR-03-38

October 2003

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Abstract

This document is intended for researchers who will be using the MORSE simulator for their team-oriented experiments. It specifies some initial criteria that can be used to evaluate the performance of the test subjects. This document also specifies the log events that are generated by MORSE and that can be used for such evaluations.

Acknowledgements

This work was completed under National Aeronautics and Space Administration Grant NCC21317. The views and conclusions contained in this document are those of the authors and should not be interpreted as presenting the official policies or position, either expressed or implied, of the National Aeronautics and Space Administration or the U.S. Government unless so designated by other authorized documents. The co-principal investigators for this grant are Bonnie E. John and Katia P. Sycara. Co-authors Joseph A. Giampapa, Rahul Singh, and Katia P. Sycara are of the Robotics Institute. Co-authors Sandra L. Esch and Bonnie E. John are from the Human-Computer Interaction Institute.

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1 Introduction

In the MORSE Range Operations Simulation Task three radar station operators must share resources and views on the launch range in order to minimize the risk that adverse weather conditions and vehicles within the launch range will have a negative impact a launch. The reader is referred to the MORSE user guide [13] for a full description of the scenario and range of actions and judgements in which the operators must engage.

Three broad criteria, partially inspired by [2], will be used to evaluate the performance of the MORSE test subjects, both at the individual and team levels, where appropriate:

1. the quality of test subjects' decisions and the impact of those decisions on increasing or minimizing risks at the time of launch;
2. the degree of coordination of the test subjects, as a team; and
3. the resource and operating costs that the test subjects incur in executing their tasks.

The MORSE simulator is designed to allow researchers to configure experiments that vary the emphasis of the above three factors on outcomes that may range in tolerances to risk from low to high. Researchers can do so by configuring different MORSE scenarios and by varying the costs of using simulated resources.

This document explains some evaluation criteria that can be determined from the MORSE simulator for each of the three categories, above, and the log events that can be used for identifying them.

2 Performance Metrics

Performance metrics for quality, cost, and coordination are described in the following sections.

The MORSE experiments can be parameterized by tolerance to risk. There could be zero tolerance to risk, in which all pre-launch criteria must be met. For example, a zero tolerance policy would stipulate that there be no incursions or interceptors in the no-fly zone. Alternatively, there could be different degrees of tolerance to risk, such as allowing different numbers of incursions and interceptors to remain in the no-fly zone at the time of launch, with the understanding that they might pose a risk to the launch or to themselves. For now, the assumption that we make is that there will be a zero tolerance to risk when conducting range operations and deciding whether or not to launch the space craft.

Each MORSE range operation scenario will be evaluated and rated in terms of the following metrics for its level of difficulty. This evaluation and rating will be based on the actions that the team should perform to efficiently and cost-effectively conduct the range operations, as opposed to absolute knowledge about the actual data and content of the scenario. For example, a scenario will be rated in terms of how often MORSE Station operators should activate a radar or check the weather of a weather cell in the course of the range operations. Scenario rating will not be made on the knowledge of the final outcome. For example, if the decision not to launch can be determined by checking the temperature in one weather cell in the final hour of range operations, then the ideal score for the scenario would be the cost incurred by deploying a balloon to that cell. Such scores would be impossibly low and therefore unusable as indicators of expert team performance.

A team is considered to have achieved an expert level of proficiency at performing range operation tasks when its performance on tasks approaches the values of the operational costs of the scenario.

2.1 Quality

This section lists the different quality metrics that are tracked by MORSE.

2.1.1 Unwithdrawn Incursions

The number of incursions that are within the no-fly zone at the conclusion of the scenario. Such vehicles may include incursions that were intercepted but have not yet left the no-fly zone. The number of unwithdrawn incursion shall be computed at the termination of the simulation.

2.1.2 Unwithdrawn Interceptor

The number of interceptors that are within the no-fly zone at the conclusion of the scenario, including those that are tasked to intercept incursions or are in transit to another deployed location.

The degree to which they are considered a risk to the launch could be a tunable parameter for a scenario. For example, if there should be no interceptor vehicles in the no-fly zone (NFZ), then the station operators should clear all interceptors before the launch. If some risk is tolerated, then a certain number of interceptors may be in the NFZ at conclusion of the scenario.

2.1.3 Launch Miscalculation

This metric indicates when a MORSE station team makes an incorrect decision about whether or not to launch. That is, if the range conditions are too dangerous or risky to launch, and the team decides to launch, then a launch miscalculation flag will be set for the whole team. Note that in the event of a disagreement among the three MORSEStation operators, the final decision will be to not launch the space vehicle.

2.2 Costs

2.2.1 Balloon Costs

Every station has an unlimited number of balloons at its disposal. In the course of the scenario, station operators will need to deploy balloons to weather cells along the trajectory to test for certain weather conditions. Weather changes in a cell once every simulated hour, and the weather report from a balloon is valid for the hour in which the weather reading was taken. While there is no automatic or programmatic means by which a MORSEStation operator can share weather information for a cell with the other operators, one can communicate weather reports via the MORSEStation chat window.

Weather balloon costs are structured as follows. There is a one-time unit charge for each balloon and its instrumentation. There is a travel charge for the balloon which increments each second of real time of travel from its release point to its destination. Finally, there is a weather reporting charge, that is charged for transmitting the report to the MORSEStation.

The cost per MORSEStation of deploying weather balloons is the sum of each individual weather balloon deployment for that station. The total team cost of deploying weather balloons is the sum of all individual MORSEStation weather balloon deployments.

2.2.2 Radar Costs

A MORSEStation operator must activate a radar to be able to detect an incursion. The cost of activating a radar is determined by the range of the radar times the amount of time, in real clock seconds, that the radar is activated. There is a one-time charge for activating the radar, as well. Costs are calculated on a per-radar, per-station basis. If two MORSEStation operators activate the same radar, they will incur the same costs for using that radar. Radar costs are calculated as they are incurred.

2.2.3 Interceptor Costs

An interceptor incurs a one-time activation cost as soon as it is activated by a MORSEStation operator. There is also a cost for maintaining the interceptor in an activated state, that is incremented every second of real clock time that the interceptor is active. An activated interceptor may be ordered to do one of two tasks: either to *deploy* to a new location, or to *intercept* an incursion. A third, “task” cost is added to the cost of the interceptor every time it is tasked to *deploy* or *intercept*. This cost is also incremented every second of real clock time that the interceptor is executing its task.

2.2.4 Total Station Costs

The costs for operating a MORSEStation are calculated as the sum of the balloon, radar, and interceptor costs. They are calculated as they are incurred.

2.2.5 Total Team Costs

The costs for the whole team are calculated as the sum of the costs for the three MORSEStations. This is calculated as the individual station costs are incurred.

2.3 Coordination

We have identified the following indicators of coordination among the MORSE team members. Although none of these are tracked while the simulation is executing, it is possible to recover this information from the log file of an executed simulation scenario.

2.3.1 Weather Data Sharing

The monitoring of weather data is a continuous activity throughout the simulation scenario. Since the stations have overlapping areas of competence, it is possible that they coordinate with each other so that only one operator will check the weather for a cell. The degree to which the operators share weather data can be determined from the simulation log file by examining *Team Communication* (c.f. Section 3.12) and *Weather Report* (c.f. Section 3.13) events.

2.3.2 Interceptor Overallocation

It is possible when more than one interceptor are tasked, either by the same operator or by different operators, to intercept the same incursion. This can be determined by examining *Interceptor Deployed* (c.f. Section 3.6), *Incursion Intercepted* (c.f. Section 3.4), and *Interceptor Aborted* (c.f. Section 3.5) events in the log file.

2.3.3 Team Launch Disagreement

It is possible to determine if the individual MORSEStation operators were in agreement about whether to launch or not by examining the *Launch Status Changed* (c.f. Section 3.7) events in the simulation log file.

3 Log Events

This chapter explains the type of information that will be determined from events that are logged while MORSE is running a simulation scenario. Time is tracked in milliseconds of resolution.

3.1 Balloon Deployed

This event records the time that a user requests the deployment of a weather balloon to a specified location.

It does not indicate the time that the weather balloon took to travel to its destination, as that can be recovered from the time stamp associated with the *Weather Report* (c.f. Section 3.13) event.

Log Name: Name=**DeployBalloon**
Time Stamp: TimeStamp=mm/dd/yyyy hh:mm:ss:ms [am|pm]
Time Stamp: ClockTime=sss (seconds from start of simulation)
Station Name: From={**Alpha, Bravo, Charlie**}
Destination: DestLat=nnn.nnnnnnn, DestLng=nnn.nnnnnnn}
Destination: GridRow=nn, GridCol=nn

3.2 Incursion Entered Radar

This event records the time at which an incursion arrives from outside a radar illumination field, touches its circumference and enters it. The event is logged whether or not the radar is turned on. This log event also indicates if an incursion is under a radar at the time that the simulation is initiated.

An incursion that tangentially touches the circumference of a radar but does not enter the radar's illumination field will record both an *Incursion Entered Radar* event and an *Incursion Exited Radar* (c.f. Section 3.3) event.

Log Name: Name=**IncEnterRadar**
Time Stamp: TimeStamp=mm/dd/yyyy hh:mm:ss:ms [am|pm]
Time Stamp: ClockTime=sss (seconds from start of simulation)
Station Name: From={**Alpha, Bravo, Charlie**}
Incursion ID: IncID=nnnnnnnnnnnn (long int, of 12 digits)
Radar ID: RadarID=nnnnnnnnnnnn (long int, of 12 digits)

One station name is written per log event. If an incursion enters the field of view of a radar that can be controlled by two or more stations, then two or more separate log events will be generated. The *ClockTime* time stamps will be identical, but the *TimeStamp* time stamps will differ by roughly 30 milliseconds.

3.3 Incursion Exited Radar

This event records the time at which an incursion is within a radar illumination field, touches its circumference and leaves it. The event is logged whether or not the radar is turned on.

An incursion that tangentially touches the circumference of a radar but does not enter the radar's illumination field will record both an *Incursion Entered Radar* (c.f. Section 3.2) event and an *Incursion Exited Radar* event.

Log Name: Name=**IncExitRadar**
Time Stamp: TimeStamp=mm/dd/yyyy hh:mm:ss:ms [am|pm]
Time Stamp: ClockTime=sss (seconds from start of simulation)
Station Name: From={**Alpha, Bravo, Charlie**}
Incursion ID: IncID=nnnnnnnnnnnn (long int, of 12 digits)
Radar ID: RadarID=nnnnnnnnnnnn (long int, of 12 digits)

One station name is written per log event. If an incursion exits the field of view of a radar that can be controlled by two or more stations, then two or more separate log events will be generated. The *ClockTime* time stamps will be identical, but the *TimeStamp* time stamps will differ by roughly 30 milliseconds.

3.4 Incursion Intercepted

This event records the time at which an incursion is intercepted by an interceptor within the no-fly zone.

This log event does not indicate the amount of travel time for the interceptor and incursion to move outside of the impact lines. Nor does it indicate interceptors that were tasked to intercept an incursion but somehow failed to rendezvous with the incursion.

Log Name: Name=**InterceptInc**
Log Name: ResType=**Interceptor**
Time Stamp: TimeStamp=mm/dd/yyyy hh:mm:ss:ms [am|pm]
Time Stamp: ClockTime=sss (seconds from start of simulation)
Station Name: From={**Alpha, Bravo, Charlie**}
Interceptor ID: IntID=nnnnnnnnnnnn (long int, of 12 digits)
Inter. Location: IntLat=nnn . nnnnnnn, IntLng=nnn . nnnnnnn}
Inter. Location: IntGridRow=nn, IntGridCol=nn
Incursion ID: IncID=nnnnnnnnnnnn (long int, of 12 digits)
Incur. Location: IncLat=nnn . nnnnnnn, IncLng=nnn . nnnnnnn}
Incur. Location: IncGridRow=nn, IncGridCol=nn

3.5 Interceptor Aborted

An interceptor may have any one of three states: *untasked*, *deploy*, or *intercept*. This event records the time at which an interceptor that is tasked to either *deploy* to a location or to *intercept* an incursion has had its task aborted or changed. This log event does not indicate the reason that the intercept was aborted.

Log Name: Name=**Abort**
 Log Name: ResType=**Interceptor**
 Time Stamp: TimeStamp=mm/dd/yyyy hh:mm:ss:ms [am|pm]
 Time Stamp: ClockTime=sss (seconds from start of simulation)
 Station Name: From={**Alpha, Bravo, Charlie**}
 Interceptor ID: ResID=nnnnnnnnnnnn (long int, of 12 digits)
 Interceptor Location: Lat=nnn . nnnnnn, Lng=nnn . nnnnnn}
 Interceptor Location: GridRow=nn, GridCol=nn
 Interceptor State: State={**deploy, intercept**}

Please note that *interceptor state* is scheduled for a future release of MORSE.

3.6 Interceptor Deployed

This event records the time at which an interceptor has been tasked by a MORSEStation operator to move to a new location.

Log Name: Name=**DeployResource**
 Log Name: ResType=**Interceptor**
 Time Stamp: TimeStamp=mm/dd/yyyy hh:mm:ss:ms [am|pm]
 Time Stamp: ClockTime=sss (seconds from start of simulation)
 Station Name: From={**Alpha, Bravo, Charlie**}
 Interceptor ID: ResID=nnnnnnnnnnnn (long int, of 12 digits)
 Interceptor Location: Lat=nnn . nnnnnn, Lng=nnn . nnnnnn}
 Interceptor Location: GridRow=nn, GridCol=nn
 Destination Location: Lat=nnn . nnnnnn, Lng=nnn . nnnnnn}
 Destination Location: GridRow=nn, GridCol=nn

3.7 Launch Status Changed

This event records the time at which a MORSEStation operator has changed his decision to launch or not to launch. Since the default decision is *No-Go*, it is possible that no *Launch Status Changed* events are logged. An operator may change his mind several times in the course of the one simulated hour of decision time, so there may be multiple *Launch Status Changed* events in the log file.

Log Name: Name=**LaunchStatusChange**
 Time Stamp: TimeStamp=mm/dd/yyyy hh:mm:ss:ms [am|pm]
 Time Stamp: ClockTime=sss (seconds from start of simulation)
 Station Name: From={**Alpha, Bravo, Charlie**}
 Status: Status={**go, nogo**}

3.8 Resource Activated

This event records the time at which a resource has been acquired by a MORSEStation operator. The two resources that may be acquired are either an **interceptor** or a **radar**.

Any MORSEStation operator may acquire a radar resource at any time in the simulation. This is not true for an interceptor. If an interceptor has been acquired by

one MORSEStation operator and a second MORSEStation would like to use it, then that second operator must explicitly request the use of that interceptor via a *Resource Request* (c.f. Section 3.10).

```

Log Name: Name=ResourceActivate
Log Name: ResType={Interceptor, Radar}
Time Stamp: TimeStamp=mm/dd/yyyy hh:mm:ss:ms [am|pm]
Time Stamp: ClockTime=sss (seconds from start of simulation)
Station Name: From={Alpha, Bravo, Charlie}
Resource ID: ResID=nnnnnnnnnnnn (long int, of 12 digits)
Resource Location: Lat=nnn.nnnnnn, Lng=nnn.nnnnnn}
Resource Location: GridRow=nn, GridCol=nn

```

3.9 Resource Deactivated

This event records the time at which a resource has been released by a MORSEStation operator. This event is also generated if the resource is an interceptor and it was released in response to a *Resource Request* (c.f. Section 3.10).

```

Log Name: Name=ResourceDeActivate
Log Name: ResType={Interceptor, Radar}
Time Stamp: TimeStamp=mm/dd/yyyy hh:mm:ss:ms [am|pm]
Time Stamp: ClockTime=sss (seconds from start of simulation)
Station Name: From={Alpha, Bravo, Charlie}
Resource ID: ResID=nnnnnnnnnnnn (long int, of 12 digits)
Resource Location: Lat=nnn.nnnnnn, Lng=nnn.nnnnnn}
Resource Location: GridRow=nn, GridCol=nn

```

3.10 Resource Request

This event records that time at which one MORSEStation operator asks another MORSEStation operator if he may acquire the latter's resource.

If the latter honors the request, then a *Resource Deactivated* (c.f. Section 3.9) event is generated for the first MORSEStation operator, and a *Resource Activated* (c.f. Section 3.8) event is generated for the requesting MORSEStation operator. If the request is declined, no further events are generated as a consequence of this request.

Presently, the only resource for which this event will be generated is an **Interceptor**.

```

Log Name: Name=ResourceRequest
Log Name: ResType=Interceptor
Time Stamp: TimeStamp=mm/dd/yyyy hh:mm:ss:ms [am|pm]
Time Stamp: ClockTime=sss (seconds from start of simulation)
Owning Station: From={Alpha, Bravo, Charlie}
Requesting Station: RequestFrom={Alpha, Bravo, Charlie}
Resource ID: ResID=nnnnnnnnnnnn (long int, of 12 digits)
Resource Location: Lat=nnn.nnnnnn, Lng=nnn.nnnnnn}
Resource Location: GridRow=nn, GridCol=nn

```

3.11 Simulation Complete

This log event indicates the time at which the entire simulation is complete. It also indicates the concluding launch status.

Log Name: Name=**SimulationComplete**
Time Stamp: TimeStamp=mm/dd/yyyy hh:mm:ss:ms [am|pm]
Time Stamp: ClockTime=sss (seconds from start of simulation)
Launch Status: LaunchStatus={**Launch, NoLaunch**}

3.12 Team Communication

This event records the time at which a text message is sent from one MORSEStation operator to the other operators.

Log Name: Name=**ChatMsg**
Time Stamp: TimeStamp=mm/dd/yyyy hh:mm:ss:ms [am|pm]
Time Stamp: ClockTime=sss (seconds from start of simulation)
Station Name: From={**Alpha, Bravo, Charlie**}
Message Text: message text string

3.13 Weather Report

This event records the weather in the weather cell. Weather reports are valid for an entire cell, and are valid for one hour of simulated time.

The log files will reveal two events that occur in the same millisecond. The first event, *WeatherQuery*, is the time at which the MORSECommand receives the query from a MORSEStation for the weather in a weather cell. The second event, *WeatherResponse*, is the time at which the MORSECommand sends out the message with the weather data.

Log Name: Name=**WeatherResponse**
Time Stamp: TimeStamp=mm/dd/yyyy hh:mm:ss:ms [am|pm]
Time Stamp: ClockTime=sss (seconds from start of simulation)
Station Name: To={**Alpha, Bravo, Charlie**}
Weather Cell: Lat=nnn . nnnnnn, Lng=nnn . nnnnnn}
Temperature: Temperature=nn . nnnnnn (degrees Fahrenheit)
Pressure: Pressure=nn . nnnnnn (units)
Humidity: Humidity=nn . nnnnnn (units)
Wind Speed: WindSpeed=nn . nnnnnn (units)
Wind Direction: WindDir=nn . nnnnnn (degrees, North=0)

4 Glossary

African Gates The part of the launch range where the space vehicle enters into earth orbit. Beyond the African Gates there is no danger of debris falling on populous areas, should there be a mishap during launch. The African Gates are represented as a break in the closed figure that the impact lines (ILs) would have formed.

Impact Lines Within the MORSE simulation the impact lines indicate a likely debris field area, should there be a mishap during launch. The impact lines are represented as two lines that originate from the launch site at Cape Canaveral, and diverge from each other as they extend eastward to the West African coast. From the West African coast, they then extend in a north-south direction until they reach the African Gates.

Incursion A vehicle that enters or is within the no-fly zone of the launch range, which is indicated by the impact lines. An incursion vehicle has the following properties:

1. it can only be detected by an active radar station,
2. it cannot be directly tasked and commanded by a MORSE station operator,
3. it can only be intercepted when it is within the launch range. That is, if it is approaching an impact line, but has not crossed it into the no-fly zone, it cannot be intercepted, and
4. it must obey and follow an interceptor after it has been intercepted.

Interceptor A vehicle that can be tasked by a MORSE station operator. An interceptor vehicle has the following properties:

1. its location, direction (or bearing), and speed can be known to the MORSEStation operators even without the aid of an active radar station,
2. it can be directly tasked and commanded by a MORSEStation operator,
3. it can only be tasked and commanded by its owner,
4. it can move anywhere within the view of its MORSEStation owner, including out of the no-fly zone of the launch range,
5. it can be tasked to intercept incursions, but only those incursions within the no-travel zone of the launch range.

Launch Range The entire view of the MORSE simulation. This corresponds to the entire map view that can be edited in the MORSECommand Scenario Editor. The individual views of the MORSEStations only represent a limited perspective on the entire launch range.

Launch Trajectory The anticipated path that a launch vehicle will follow from lift-off until it enters into earth orbit at the African Gates. Launch trajectories vary per launch vehicle.

No-Fly Zone (NFZ) This is the zone in which no unauthorized vehicles may travel, and in which there may be a limit on the number of authorized vehicles or on what activities they may perform. The west-east area of the no-fly zone extends from the point of launch (e.g. Cape Canaveral) where debris from the launch of a space vehicle might fall to the African Gates in the east. The north-south boundaries are marked by the impact lines (ILs).

Radar Station The sensor resource that must be active in order for an unauthorized vehicle to be detected.

Vehicle Any vehicle operating in the MORSE simulation. We classify them as being either *authorized* or *unauthorized* vehicles. Of the authorized vehicles, MORSE is concerned with the interceptors. Of the unauthorized vehicles, MORSE is concerned with those that are either within the no-fly zone of the launch range, or those that might enter the NFZ. An unauthorized vehicle that enters the no-fly zone is called an incursion. All vehicles in MORSE are presumed to be air vehicles, that can travel in the air, over sea or across land. Vehicles have a location, direction (or bearing), and speed, that is measured in unspecified *units*.

Weather Balloon Station The point from which a weather balloon is launched. This point is indicated by a yellow flag. There is only one weather balloon station per MORSEStation view. Weather balloons travel from a weather balloon station by a small vehicle (not represented in the simulation) until they reach their destination within a weather cell.

Weather Balloon Reports the weather for a weather cell. The cell that they report can be located by clicking on the weather information in the information pane. To reduce the complexity of the simulation, weather balloons only report the weather from a cell that is traversed by the launch trajectory. All other weather cells will produce an *undefined* weather report. Weather information is only valid for one hour, although it is displayed from the time of the balloon's arrival until the end of the simulation.

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