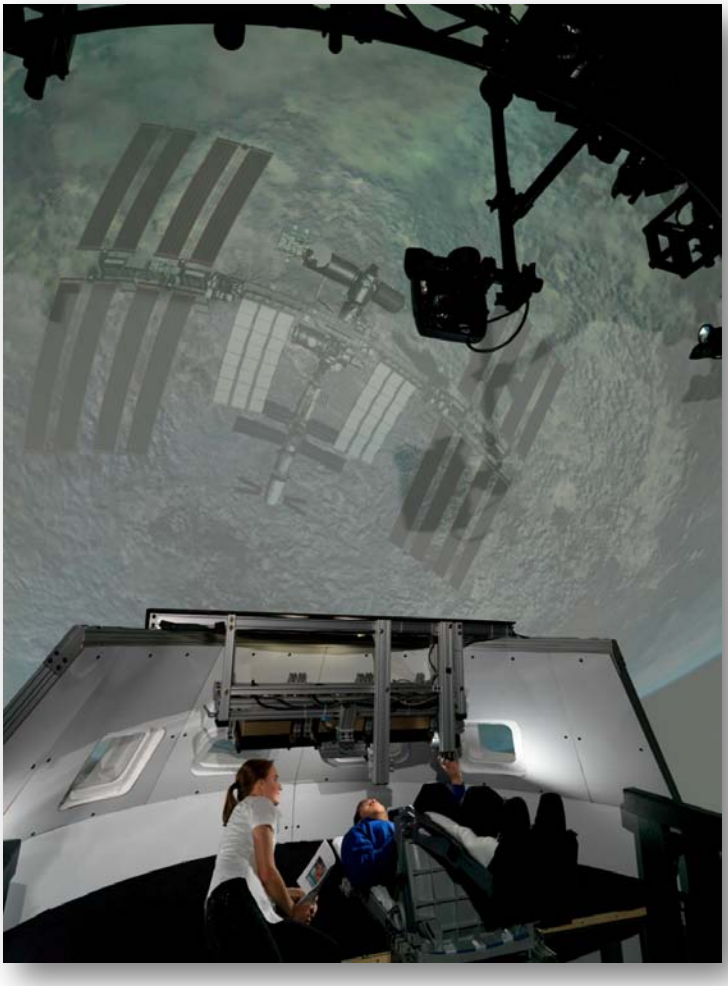
Abstract – Systems Engineering Simulator (SES) Simulator Planning Guide

The simulation process, milestones and inputs are unknowns to first-time users of the SES. The Simulator Planning Guide aids in establishing expectations for both NASA and non-NASA facility customers. The potential audience for this guide includes both internal and commercial spaceflight hardware/software developers. It is intended to assist their engineering personnel in simulation planning and execution. Material covered includes a roadmap of the simulation process, roles and responsibilities of facility and user, major milestones, facility capabilities, and inputs required by the facility. Samples of deliverables, facility interfaces, and inputs necessary to define scope, cost, and schedule are included as an appendix to the guide.

JSC-XXXXX

Systems Engineering Simulator (SES)

Simulator Planning Guide



National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
Houston, Texas 77058

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1.0 Systems Engineering Simulator

The Systems Engineering Simulator (SES) is a real-time, crew-in-the-loop engineering simulator for the space station and advanced programs. It provides the ability to test changes to existing space vehicles and flight software, test the interaction of a new vehicle system with existing systems, create models of new vehicles (that may or may not exist yet) for engineering analysis, and evaluate display and control concepts and modifications. All of these functions are performed in a controlled, yet flexible, development environment. Models and capabilities developed for one customer can be used by other customers.

Services Provided

- Simulation of multiple free-flying vehicles with accurate six-degree-of-freedom equations of motion
  - Docking contact dynamics
  - Aerodynamics
  - Thruster plume impingement
  - Vehicle control systems
  - Robotic manipulator dynamics
- Engineering studies
  - Proof of concept: Test of experimental operations to validate their values
  - Operational feasibility: Flight-like environment within the environment of the simulator
  - Design assessment: Analysis of vehicle interactions
- Mission support and evaluation
  - Procedure development: Flight procedure development through simulation of missions
  - Training: Training of flight crew, controllers, and other personnel in rendezvous/proximity operations
  - Flight support: 24-hour support during missions to respond to on-orbit contingencies

SES Beta Dome Orion Reclined Cockpit

Point of Contact

Lab Manager, Michael McFarlane
Johnson Space Center
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(281) 483-1539
michael.r.mcfarlane@nasa.gov

Capabilities and Specifications*

Supported Vehicles

- ~~Operational Vehicles~~
  - International Space Station (ISS)
  - H-II Transfer Vehicle (HTV)
- ~~Conceptual Vehicles~~
  - Dragon
  - Cygnus
  - Orion
  - ~~Altair~~
  - Space Exploration Vehicle

Scenarios

- Launch and Ascent
- On-Orbit Operations
- Rendezvous and Docking
- Robotic Grappling and Berthing
- Descent and Landing

Rapid Prototyping

- D&C Prototyping
- Window Evaluations
- Helmet Eyepoint Evaluations
- Hand Controller Evaluations
- Handling Quality Assessment

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Visual Systems

The SES domes use multiple projectors to provide wide-angle cross-cockpit viewing. Dome visuals are rendered by a variety of graphics packages:

- Enigma (AGEA)
- DOUG
- EDGE
- OpenSceneGraph

Dome Specifications

- Alpha Dome
  - 180° horizontal viewing angle
  - –30° to 105° vertical viewing angle
  - 15° cap
- Beta Dome
  - 240° horizontal viewing angle
  - –60° to 120° vertical viewing angle
  - 30° cap
- Mini Dome
  - 160° horizontal viewing angle
  - –30° to 30° vertical viewing angle

Vehicle mockups may be quickly swapped in and out of the SES domes with little downtime.

* See Appendix A, Facility Configuration, for additional facility capabilities.

2.0 Safety and Health

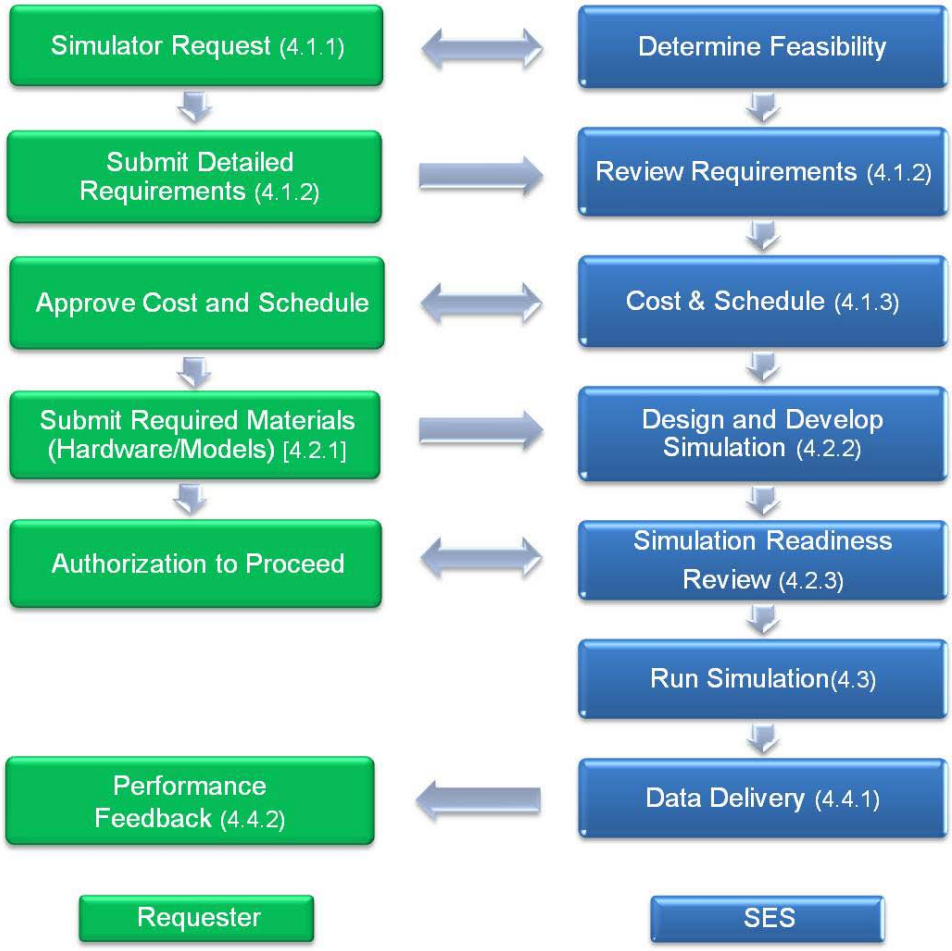
Safety is an integral part of the culture at the National Aeronautics and Space Administration (NASA). Management, leadership, and employee involvement from all organizations is critical to the success of NASA's safety program. While visiting the Johnson Space Center (JSC), the requester shall follow all facility-specific safety and health requirements. A facility safety briefing shall be provided to all personnel prior to the start of the simulation activity. The safety briefing will include a review of the facility safety rules, potential hazards, and emergency procedures.

3.0. Export Controlled and Proprietary Information

JSC provides for protection of export controlled and proprietary information and hardware throughout the analysis process. The Requester shall clearly mark all export controlled or proprietary hardware items, models, and data provided with a notice of restriction on disclosure or usage. The Laboratory Manager shall safeguard export controlled or proprietary items from unauthorized use and disclosure and ensure that they remain secure within the laboratory and are properly sequestered. Access to the laboratory is ~~restricted to facility personnel and escorted visitors~~controlled. Models shall be returned to the Requester or disposed of in accordance with the Requester's instructions at the completion of the activity.

4.0 Study Support Process

The following flowchart outlines the basic roadmap and significant milestones between the initial analysis request and delivery of data. The flow is separated between Requester actions and Facility actions, highlighting interactions and inputs between the Requester and the SES.


Simulator Request (4.1.1)
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Review Requirements (4.1.2)
Approve Cost and Schedule
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Simulation Readiness Review (4.2.3)
Run Simulation(4.3)
Performance Feedback (4.4.2)
Data Delivery (4.4.1)
Requester
SES

4.1 Simulator Request Phase

The simulator request phase establishes the relationship between the Requester and the Laboratory Manager. The Requester shall contact the Laboratory Manager to request a simulation. This contact is necessary to define the initial requirements for the simulation. The Laboratory Manager will review the request to determine if the SES can meet the stated objectives.

Inputs:	Requester provides simulator request, identifies objectives for study
Activities:	Laboratory Manager reviews request to determine feasibility
	Requester provides detailed requirements
Outputs:	Laboratory Manager delivers estimated cost and schedule

4.1.1 Simulator Request

The simulator request outlines the scope of the work, objectives, and schedule. A Simulator Request Worksheet is provided in Appendix B. This worksheet addresses the basic requirements for utilizing the SES. It is suggested that the Requester complete this worksheet to facilitate the development of a preliminary cost and schedule estimate. Contact the Laboratory Manager if you have questions about completing the Simulator Request Worksheet. At a minimum, the request should include the following information:

Scope of Work

A brief description of the simulation requirements, including, but not limited to, the following:

- General information (e.g., name of study, requested dates, contact information, participants)
- Requested services
- Study overview (e.g., vehicle characteristics, simulation environment, operations to be performed, procedures)
- Cockpit (use existing cockpit or one provided by Requester or fabricated by SES)
- Simulation information (include delivery date and details of simulation, which might already exist or may be provided by Requester or designed by SES)
- Graphics/scenes information (include details of graphics models, which might already exist or may be provided by Requester or designed by SES)
- Special hardware/software setup
- Required products (e.g., recorded simulation data, tables, reports, plots, video recording, audio recording, scene/graphics capture)

4.1.2 Requirements

A complete understanding of requirements is mandatory for a successful study. Requirements must be defined and reviewed so that the test team understands the effect of the requirements on cost, schedule, and facility preparation. Requirements review meetings may be necessary in order to discuss the objectives of the study, questions about the Simulator Request, or special considerations for the study. The Requester shall provide detailed requirements, including, but not limited to, the following:

- Cockpit Requirements

  The SES maintains a limited number of cockpits to support current simulation customers. Please consult with the Integrated Studies Team (IST) Support Engineer prior to designing your cockpit. In some circumstances, dedicated cockpits may not be necessary for your simulation due to the availability of, or modification to, existing cockpits. Coordination between the Requester and the IST Support Engineer should begin very early in the process, as the design and fabrication of cockpits can be more time-consuming than initially anticipated. Current cockpits maintained by the SES include the following:

  - ISS Cupola
  - Multiple Orion Cockpits
  - Space Exploration Vehicle (SEV)
  - Various configurable cockpits

- Graphics/Simulation Model Requirements

  The SES provides state-of-the-art graphics rendering and simulation model development software. Software available for use is described in Appendix C. The requester shall define graphics and simulation models to be used in the study, including, but not limited to, the following:

  - Models to be provided by Requester
  - Existing SES models to be utilized
  - Models to be designed by the SES
  - Responsibility for integration of models
  - Special requirements

- Specific details about operations to be performed (e.g., docking, entry, landing)

4.1.3 Cost and Schedule

A detailed cost and schedule shall be developed by the Laboratory Manager and approved by the Requester. The schedule shall allow adequate time for review and approval of requirements, preparation for the simulation, and delivery of any models. The schedule of other

work and maintenance activities will be reviewed and potential conflicts shall be addressed by the Laboratory Manager.

4.2 Simulator Preparation Phase

Simulator requirements, cost, and schedule are finalized during the simulator preparation phase. The Requester shall provide detailed requirements and documentation to the IST Support Engineer.

Inputs:	Requester approves cost and schedule and submits required materials and documentation
Activities:	SES begins simulation development
Outputs:	SES holds Simulation Readiness Review

4.2.1 Required Materials

The Requester shall provide models, drawings, and documentation as requested by the SES. Materials must be received before the IST Support Engineer can properly prioritize, plan, and schedule the work. The Requester shall provide required materials, including, but not limited to, the following:

- Procedures and reference information
- Cockpit design
- Simulation models
- Graphics models
- Special hardware or software

The simulation materials are used to design scenes and develop the desired simulation. We can accept files by e-mail, through a File Transfer Protocol (FTP) site, or via standard mail.

1. E-mail materials to the IST Support Engineer.
2. The IST Lead will send an invitation to the NASA FTP site for uploading and sending files.
3. Mail to the Johnson Space Center, Attention: Amy Efting, Mail Code: ER7, 2101 NASA Parkway, Houston, Texas 77058.

Note: Consult with the IST Support Engineer prior to shipping cockpits or any physical hardware.

4.2.2 Design and Development of the Simulation

The IST Support Engineer will begin the design of the simulation following approval of the cost and schedule. Completion of the design is contingent upon receipt of the required materials. Scenario design and simulation development is a highly-integrated activity. Depending on the

complexity of the simulation, the IST Support Engineer may request interim simulation checkouts to verify that requirements are being met. A final simulation checkout shall be performed prior to scheduling the Simulation Readiness Review.

4.2.3 Simulation Readiness Review

A Simulation Readiness Review will be held to ensure the completion of developed simulation, review the simulation schedule, and brief simulation participants. Approval to proceed with the study is provided by the Requester with concurrence from the Laboratory Manager.

4.3 Simulation Execution Phase

The IST Support Engineer will begin the simulation following approval from the Simulation Readiness Review. Study participants shall arrive at the agreed-upon time. The SES encourages Requester participation throughout the simulation. The SES will provide space for the Requester and study participants to set up required hardware and equipment.

Inputs:	Approval to begin simulation
	Study participants arrive at SES
Activities:	SES runs simulation
Outputs:	Simulation completed

4.3.1 Change Request

Changes to the scope of the simulation shall be approved by the Requester. Deviations that result in a major change to the scope of the analysis may require a delta requirements review or a change to the cost and schedule. Changes shall be coordinated through the Laboratory Manager.

4.3.2 Facility Equipment

The facility equipment is meant for use by JSC personnel. Prior arrangements shall be made with the IST Support Engineer for potential use of this equipment by the Requester. The duration and type of use will be identified prior to authorization for use. JSC workstations are not available for use by Requester personnel. This is necessary to protect the integrity of the laboratory. The Requester shall make prior arrangements with the IST Support Engineer if a dedicated workstation is required during the simulation. The Requester is encouraged to bring a laptop for use during the test. Internet access is available in the facility. Pre-coordination with the IST Support Engineer is required in order to establish network access accounts prior to arrival.

4.4 Closeout Phase

Raw data shall be delivered to the Requester within 5 business days following completion of the simulation. A report or detailed analysis of the data may be delivered, if requested. The report and/or detailed analysis of the data will be delivered in accordance with the schedule agreed to by the Laboratory Manager and the Requester. The Requester shall make note of data delivery requirements in the Simulation Request Worksheet (Appendix B). The Requester shall notify the Laboratory Manager upon receipt of the data. Acceptance of the data concludes the activity.

Inputs:	Simulation completed
Activities:	Laboratory Manager returns model(s) to Requester (per Requester instructions)
	Laboratory Manager delivers reports and data to Requester
Outputs:	Requester accepts data
	Requester completes Customer Feedback form

4.4.1 Simulation Data

A simulation data package is an assembly of the results of the study. The format of the data package is normally specified by the Requester. The standard data package format includes recorded simulation data. A formal report can be provided, if required, and may include a description of the simulation and objectives, data plots, and post-processed data.

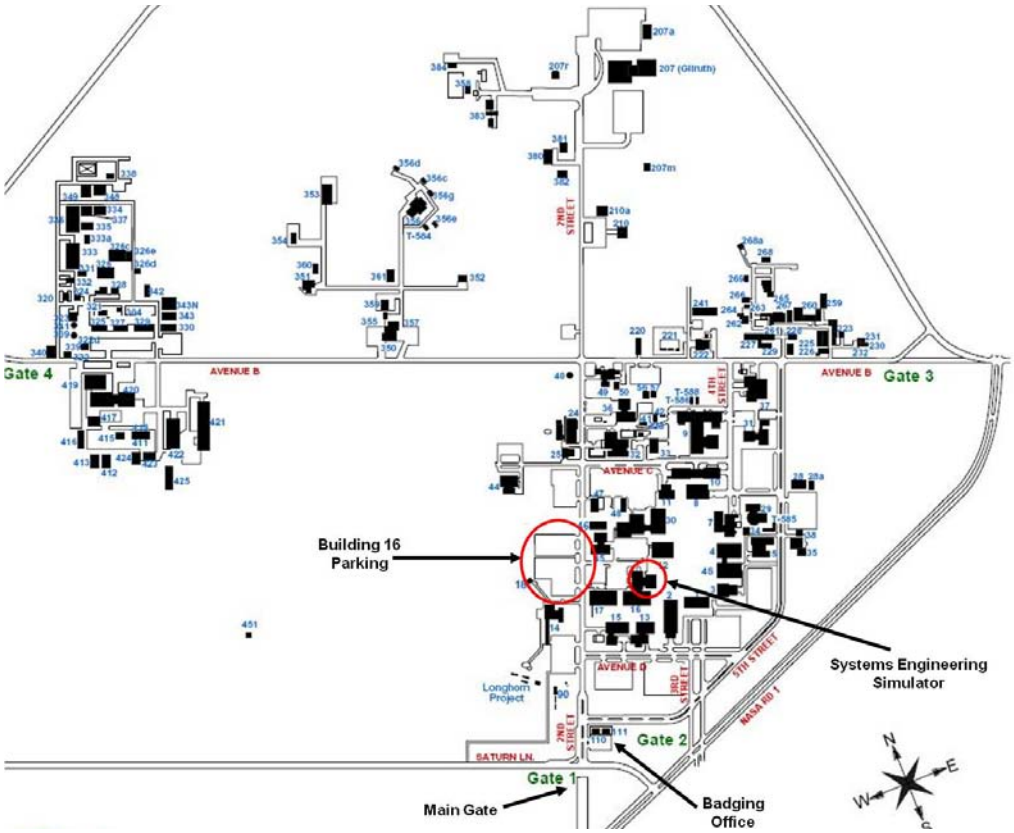
4.4.2 Customer Feedback

The SES encourages feedback from our customers. Evaluation of the services we provide enables continued improvement to our process. A Customer Feedback form is included in Appendix D. Please provide any feedback on our services to the SES Laboratory Manager. Your feedback is greatly appreciated.

5.0 Facility Access

Identification badges are required for all persons requiring access to JSC. The Laboratory Manager or designee will initiate a badge request for all Requester personnel who will be visiting the laboratory. Badge requests must be submitted at least 4 days prior to the visit to prevent badge processing delays. Badge requests for non-U.S. citizens may require a minimum of 30 business days to process. Requester personnel shall arrive at JSC Building 110 to pick up temporary identification badges. Visitors to JSC must show a current picture identification (valid driver's license, U.S. passport, government ID card).

The SES is located in JSC Building 16.



6.0 Roles and Responsibilities

Laboratory Manager – The SES Laboratory Manager coordinates the overall simulation process via discussions with the Requester.

IST Support Engineer – The IST Support Engineer for a given study works with the Requester to gather and document requirements, communicate those requirements to the development engineers, validate those requirements, and resolve all issues associated with the study. The IST Support Engineer also provides general support throughout all Requester sessions in the SES.

Requester – The entity requesting a simulation. The Requester is responsible for providing simulation requirements, verifying that objectives are met, and approving change requests.

Simulation Participant – The individual or individuals actively participating in the simulation. Simulation participants may be representatives of the Requester or the SES, or they may be NASA astronauts.

Responsibilities Matrix

Item	Requester	SES
Simulator Request Worksheet	Create	Review and provide assistance as needed
Requirements Review	Submit	Review/concur
Cost and schedule	Approve	Create and sign off
Simulation	Approve requested deviations	Perform simulation
Provide data/results	Notify Laboratory Manager of data receipt	Deliver to Requester
Review data/results	Approve	

Acronyms

AGEA	Animated Graphics for Engineering Analysis
CAD	Computer-Aided Design
CBM	Common Berthing Mechanism
CMG	Control Moment Gyro
CPU	Central Processing Unit
D&C	Deployment and Configuration
FTP	File Transfer Protocol
GDAL	Geospatial Data Abstraction Library
GN&C	Guidance, Navigation, and Control
HTV	H-II Transfer Vehicle
HUD	Heads-Up Display
IGOAL	Integrated Graphics Operations and Analysis Laboratory
ISS	International Space Station
IST	Integrated Studies Team
JEOD	JSC Engineering Orbital Dynamics
JSC	Johnson Space Center
MBDYN	Multibody Dynamics
MMS	Mobile Servicing System
MMSEV	Multimission Space Exploration Vehicle
MPCV	Multipurpose Crew Vehicle
NASA	National Aeronautics and Space Administration
POC	Point of Contact
RAM	Random Access Memory
RCS	Reaction Control System
RWS	Robotics Work Station
SES	Systems Engineering Simulator
SEV	Space Exploration Vehicle
SSRMS	Space Station Remote Manipulator System

Appendices

A. Facility Configuration

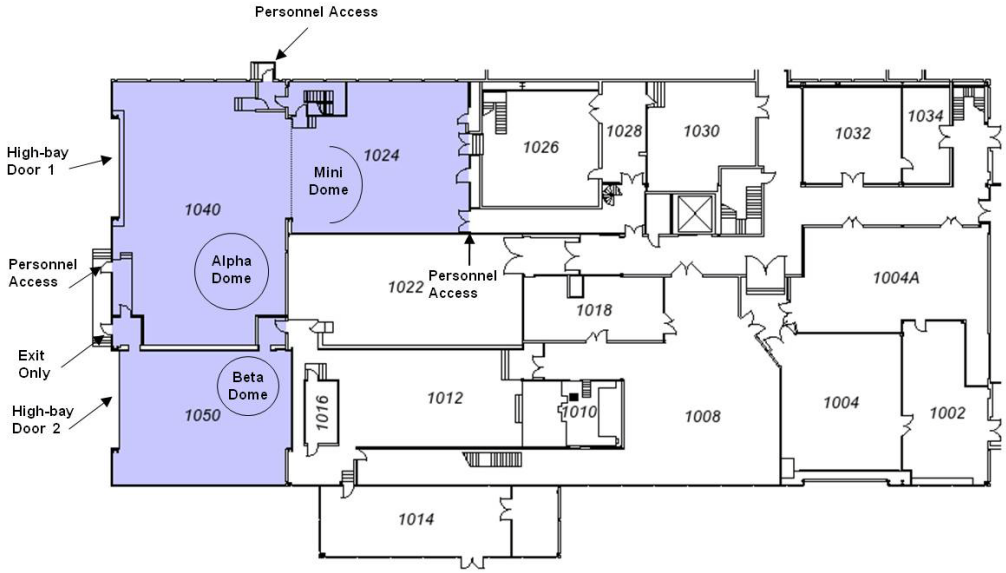
B. Simulator Request Worksheet

C. Laboratory Software

D. Customer Feedback

Appendix A Facility Configuration

Access to the SES is restricted to authorized personnel only. Visitors must be escorted through the SES at all times. The following is the floor plan for JSC Building 16N. The SES areas are highlighted in blue.



General Facility Information
• High-Bay Door Access: Rooms 1040 and 1050 doors are 28′ wide x 29′ high • Material handling equipment; dedicated site rigging support

Cockpit Integration – Beta Dome

SES Capabilities

Environment Models

- Six-degree-of-freedom equations for motion of multiple bodies
  - Combined body dynamics and transitions
- Gravity and gravity gradient
- Solar and lunar ephemerides
- Plume impingement model for proximity operations
- Aerodynamics model

Orion/Multipurpose Crew Vehicle (MPCV)

- Seated and reclined Orion cockpit mockups
  - Can be located in a dome visual system to simulate out-the-window viewing
- Orion Guidance, Navigation, and Control (GN&C) system
- Orion Reaction Control System (RCS)

International Space Station

- RCS and Control Moment Gyro (CMG) attitude control system algorithms
- Space Station Remote Manipulator System (SSRMS) with flex dynamics
  - Includes servos and gearboxes
- Robotic Work Station (RWS) with real-time SSRMS interaction through hardware and displays
- Common Berthing Mechanism (CBM) ready-to-latch model and contact dynamics model
- Cupola mockup that can be located in a dome visual system to simulate out-the-window viewing

Visuals

- Three dome screens to provide maximum field of view from vehicle mockups
- Scene models for the space shuttle, ISS, Orion, and several payloads and free flyers
- Animation
- Relocatable sun source
- Configurable cameras and eyepoints
- Computer-based video recording and image capturing

Free Flyers

- ISS resupply vehicles with active control systems that can be captured and berthed by the SSRMS:
  - HTV
  - SpaceX Dragon
  - Orbital Cygnus
- Multimission Space Exploration Vehicle (MMSEV)
  - Dock/undock with mother ship
  - Rendezvous and make contact with an asteroid surface
  - Provide pilot with active control of manipulator and standoff arms
- Advanced models and features:
  - Propulsion and control systems
  - Plume impingement geometry models
  - Aerodynamic force and moment coefficients
  - Instantaneous rate capability
  - Payload handoff between multiple robotic systems

SES Alpha Dome

SES Alpha Dome

Dome Specifications
• Dome – 180° horizontal viewing angle – –30° to 105° vertical viewing angle – 15° cap • Dome visual system utilizes eight projectors with a visual resolution of 1600 x 1200 pixels each • Dome diameter is 24′ and can accommodate cockpit/mockup volumes of 8′ x 8′ x 8′ • Mockup electric lift to eyepoint position

SES Alpha Dome – Cupola Mockup

SES Beta Dome

Beta Dome - Orion Reclined Mockup

Dome Specifications
• Dome – 240° horizontal viewing angle – –60° to 120° vertical viewing angle – 30° cap • Dome Visuals System utilizes 11 projectors with a visual resolution of 1400 x 1500 pixels each • Dome diameter is 24′ and can accommodate cockpit/mockup volumes of up to 10′ x 10′ x 10′ as defined by field-of-view requirements • 5.1 Dolby Digital sound capability • Mockup electric lift to eyepoint position

Beta Dome – Inside Orion Reclined Mockup

SES Mini Dome

SES Mini Dome – Inside Cockpit

Dome Specifications
• Dome – 160° horizontal viewing angle – –30° to 30° vertical viewing angle • Dome Visuals System utilizes eight projectors with a visual resolution of 1400 x 1500 pixels each • Dome diameter is 21′ and can physically accommodate cockpit/mockup volumes of up to 12′ wide x 10′ long x 7′ high. Mockup partial shadowing of visuals will occur and may be defined by field-of-view requirements • 5.1 Dolby Digital sound capability

SES Mini Dome

Appendix B Simulator Request Worksheet

Purpose: *The purpose of this questionnaire is to provide the customer with a means of identifying essential elements required to generate a cost and schedule estimate. Please r*eturn this form to Mike McFarlane, SES Laboratory Manager, michael.r.mcfarlane@nasa.gov.

1. Study Name:
2. Mission Designation (if applicable):
3. Dates:
    a. Expected study start date:
    b. Expected study end date:
    c. Expected product delivery date:
    d. List other milestones, blackouts, or date requirements:
4. Contact Information:

Primary POC Name	Phone	E-mail Address
Company/Agency		Role/Title

Name	Phone	E-mail Address
Company/Agency		Role/Title

Name	Phone	E-mail Address
Company/Agency		Role/Title

Name	Phone	E-mail Address
Company/Agency		Role/Title

5. Check all services that will need to be provided by the SES:

Task		Comments/Notes
☐	Data Recording/Collection	
☐	Data Processing	
☐	Data Analysis	
☐	Test Conductor	
☐	Test Subjects	
☐	Simulation Model Development	
☐	Simulation Integration	
☐	Hardware Fabrication	
☐	Hardware Integration w/ Facility	
☐	Simulation Input Data	

6. Study Overview

Give detailed description of scenario(s) to be simulated. Please include the following information:

a. Active vehicle(s) in scenario
b. Active systems on vehicles (e.g., control systems, sensors)
c. Contact surfaces to be modeled
d. Environment (e.g., Earth atmosphere, lunar surface, Mars orbit)
e. Any other information

SES has standard models (e.g., orbital dynamics, atmosphere, contact modeling). Are there any special or enhanced models required for the study?

Does the study require human-in-the-loop interaction? ☐ Yes ☐ No

If so, do test subjects need to be astronauts? ☐ Yes ☐ No

Does the study require hardware-in-the-loop interaction? ☐ Yes ☐ No

Operations to be performed (select all that apply):

a. ☐ Docking/Berthing – Specify Vehicles to Dock/Berth:
b. ☐ Ascent
c. ☐ Entry
d. ☐ Landing
e. ☐ On-orbit
f. ☐ Surface roaming
g. ☐ Robotic arm operations
h. ☐ Other:

Relevant Procedures and Reference Information:

a. List any available relevant procedures and/or test plans:

i. ☐ Available online at:
ii. ☐ Will provide electronic copy of preliminary/unpublished procedures/test plans.

b. Are there any applicable materials or information, such as CAD drawings or dimensions, that would be useful in setting up hardware or software for this study?
   i. ☐ Available online at:
   ii. ☐ Will provide electronic copy.

c. Do you have requirements documents from another facility or study that might be helpful in setting up this scenario? ☐ Yes ☐ No

   If so, can you provide the SES with a copy? ☐ Yes ☐ No

7. Cockpits To be Used (select all that apply):

SES existing cockpits:

a. ☐ Cupola
b. ☐ Orion Upright Cockpit
c. ☐ Orion Reclined Cockpit
d. ☐ Rover/MMSEV
e. ☐ Lander

Customer-provided cockpits/hardware (*Describe below*. *Please provide expected delivery date for each provided component.)*:

New Cockpits/hardware to be fabricated by the SES: (*Describe below.)*

8. Simulation Information:

Do you plan to provide a simulation for use in the SES facility? ☐ Yes ☐ No

a. If yes, please describe the simulation and how it will interface with the SES facility:

b. Please provide the expected delivery date of the simulation(s):

Do you plan to provide simulation models to be integrated into an existing SES simulation?
☐ Yes ☐ No

If yes, please specify the types of models and expected delivery date for each model:

Types	Delivery Date

If you plan to use an existing SES simulation, and have a preference on the simulation revision used, please specify here:

9. Graphics/Scenes Information:

Do you require a Dome visual system? ☐ Yes ☐ No

Do you have a preference for a graphics rendering program (If yes, please specify.)? ☐ Yes ☐ No

Will you need new graphics models implemented into the scenes for your study? ☐ Yes ☐ No
If yes, please answer the following:

a. Will you be supplying the graphics models or do you need them to be developed?
b. If you will be supplying graphics models or any data required for the SES to build graphics models, please specify the expected delivery date for each delivered item:

Do you have any special graphics requirements (e.g., overlays, animations)?

10. Special Hardware and Software setup required:

- ☐ Use Existing (No special hardware or software needed.)
- ☐ Use information from previous study/mission: *Click here to enter text.*
- ☐ Use information specified in table below:

Hardware Information

a.

Special Hardware	To Be Supplied By	Usage Limitations*	Need Date
To Be Installed By	Version/Description	Comments/Installation Location	Permanent or Returned to Supplier

b.

Special Hardware	To Be Supplied By	Usage Limitations*	Need Date
To Be Installed By	Version/Description	Comments/Installation Location	Permanent or Returned to Supplier

c.

Special Hardware	To Be Supplied By	Usage Limitations*	Need Date
To Be Installed By	Version/Description	Comments/Installation Location	Permanent or Returned to Supplier

d.

Special Hardware	To Be Supplied By	Usage Limitations*	Need Date
To Be Installed By	Version/Description	Comments/Installation Location	Permanent or Returned to Supplier

Software Information

a.

Special Software	To Be Supplied By	Usage Limitations*	Need Date
To Be Installed By	Version/Description	Comments/Installation Location	Permanent or Removed

b.

Special Hardware	To Be Supplied By	Usage Limitations*	Need Date
To Be Installed By	Version/Description	Comments/Installation Location	Permanent or Returned to Supplier

c.

Special Hardware	To Be Supplied By	Usage Limitations*	Need Date
To Be Installed By	Version/Description	Comments/Installation Location	Permanent or Returned to Supplier

d.

Special Hardware	To Be Supplied By	Usage Limitations*	Need Date
To Be Installed By	Version/Description	Comments/Installation Location	Permanent or Returned to Supplier

*Usage limitations – Is software/hardware proprietary; can it be used by others or for demonstrations?

11. Special Hardware / Software Minimum Specifications (Describe all that apply):
    a. Operating System Version:
    b. CPU:
    c. Video Card (s):
    d. RAM:
    e. Disk Space:
    f. Other:

12. Required Products

☐ Recorded sim data (specify approximate number of parameters and recording frequency):

☐ Tables (specify format):

☐ Plots (specify format):

☐ Reports (specify scope of expected reports):

☐ Scene/graphics capture (specify format and frame rate):

☐ Video recording:

☐ Audio recording:

13. Additional Requirements/ Comments:

Appendix C Laboratory Software

Enigma (AGEA)

The Integrated Graphics Operations and Analysis Laboratory creates and works with models and produces highly realistic animations of space operations. Modeling and animation are performed in Animated Graphics for Engineering Analysis (AGEA), an integrated modeling, animation and visualization tool. This tool is based on the award winning Enigma software, which was developed in-house by the Integrated Graphics Operations and Analysis Laboratory (IGOAL) team. Existing models can be read in from industry standard file formats, including AutoCAD, STEP, Stereo Lithography, WaveFront, and Inventor. Animations are rendered digitally and can be output in broadcast quality to tape or DVD or sized down as an AVI file for output to CD.

Engineering DOUG Graphics for Exploration (EDGE)

EDGE is a rendering package used in all of the on-orbit simulations (engineering and training) at JSC and is available for public release through the JSC Technology Transfer Office.

- Windows-, Mac-, and Linux-compatible
- Delivered with high-fidelity space station models
- Networked architecture for distributed image generation
- Extensible architecture using plug-ins and scripts
- Built-in recording capability
- Configurable Heads-Up Displays (HUDs) and overlays
- Real-time shadows
- Customizable planet elevations, atmospheres, and imagery
- Loads terrain data directly in GDAL formats
- Double precision and infinite z-buffer resolution
- Supports multiple model formats; additional formats may be added through plug-ins

Trick

Trick is a software package used to build and run simulations. Trick provides utilities and a simulation executive that work together to transform developer's model code into either a real-time simulation or a non-real-time simulation.

JSC Engineering Orbital Dynamics (JEOD)

JEOD is a collection of computational mathematical models that provide trajectory generation for a vehicle or vehicles by the solution of a set of dynamics models represented as differential equations. These models are comprised of an Environment model, representing the forces acting on the vehicle (vehicles), and a Dynamics model for processing and numerically integrating the equations of motion.

Multibody Dynamics (MBDYN)

The MBDYN model provides numerical solutions to the equations of motion for a collection of rigid and flexible bodies needed in the simulation of systems, such as robotic manipulators and vehicles with articulating parts. It addresses mainly open-tree topologies but can handle limited types of closed loops.

ISS Models

The SES maintains a selection of ISS models, including, but not limited to, the following:

- Control Systems
- Structural models
- Mobile Servicing System (MSS)
- Visual models
- Mechanism models

Appendix D Customer Feedback

SES CUSTOMER FEEDBACK							
Study Title:		**Name:**					
Study Start Date:	**Study End Date:**	**Company/Org:**					
		SCORE (Check or Click on Box)					
		Strongly Disagree				Strongly Agree	
SCHEDULE:		**1**	**2**	**3**	**4**	**5**	**N/A**
1. Study was initiated and completed to meet schedule requirements.		☐	☐	☐	☐	☐	☐
2. SES accommodated requested schedule.		☐	☐	☐	☐	☐	☐
DELIVERABLES:							
3. Deliverables provided met study requirements.		☐	☐	☐	☐	☐	☐
4. Deliverables were provided in an acceptable format.		☐	☐	☐	☐	☐	☐
5. Deliverables were provided in a timely manner.		☐	☐	☐	☐	☐	☐
FACILITY (Support Hardware):							
6. The facility's hardware satisfied the study requirements.		☐	☐	☐	☐	☐	☐
7. The facility was reliable during the study.		☐	☐	☐	☐	☐	☐
SUPPORT TEAM:							
8. The SES support team was helpful and knowledgeable in meeting study objectives.		☐	☐	☐	☐	☐	☐
9. The SES support team was on-time and professional.		☐	☐	☐	☐	☐	☐
OVERALL RATING:							
10. Overall experience in the SES was positive.		☐	☐	☐	☐	☐	☐
11. You would consider using this facility for future studies.		☐	☐	☐	☐	☐	☐
Note: We are interested in your comments and would like an opportunity to improve our service							
Comments/Suggestions for Improvement:							
Return to: Michael McFarlane, SES Lab Manager, michael.r.mcfarlane@nasa.gov							