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AIRCRAFT MANEUVERS FOR THE EVALUATION OF FLYING QUALITIES AND AGILITY

VOL 2: MANEUVER DESCRIPTIONS AND SELECTION GUIDE

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A set of aircraft maneuvers has been developed to augment evaluation maneuvers used currently by the flying qualities and flight test communities. These maneuvers extend evaluation to full aircraft dynamics throughout the aircraft flight envelope. As a result, a tie has been established between operational use and design parameters without losing control of the aircraft evaluation process.

Twenty maneuvers are described as an initial set to examine primarily high-angle-of-attack conditions. Perhaps as important as the maneuvers themselves is the method used to select them.

These maneuvers will allow direct measurement of flying qualities throughout the flight envelope instead of merely comparing parameters to specification values.

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Foreword

As flight control systems become capable of providing a variety of aircraft response types and aircraft flight envelopes expand to include a wider range of angle of attack and speed, the ability to predict flying qualities becomes increasingly difficult. Traditional parameters, such as modal characteristics and time delay, cannot totally capture the relationship of aircraft dynamics, task performance and pilot workload. The success of the Handling Qualities During Tracking flight test technique led to the thought that a series of demonstration maneuvers could be defined for a variety of tasks which would augment the normal aircraft flying qualities description. In order to be useful, such maneuvers must be well-defined and suited to testing, must relate to the operational use of the vehicle and must be sensitive to parameters used in the design process.

The research documented in this four-volume report series has developed a process by which these maneuvers can be defined and validated as well as an initial set of maneuvers aimed primarily at agility and the high-angle-of-attack flight regime. A key word here is initial, limited resources did not allow this effort to address all aircraft types or missions. It is hoped that as various agencies and companies conduct their own research, they will develop additional or modified maneuvers and add them to this existing set. This process will allow the maneuvers to keep pace with the changes in aircraft technology and operational missions and tasks. New maneuvers should be sent to WL/FIGC_2, WPAFB OH, 45433-7531. An updated set of maneuvers and lessons learned will be available either by mail or electronically through the ARPANET computer network. For details, contact Tom Cord at (513) 255-8674. The resulting maneuver set will provide a basis from which demonstration maneuvers for the verification section of Mil-Std-1797B can be defined.

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Preface

This series of reports proposes aircraft maneuvers and general guidelines for the piloted evaluation of aircraft flying qualities and agility. These maneuvers augment rather than replace existing flying qualities evaluation techniques and are aimed primarily at expanded flight envelopes. A process to develop new evaluation maneuvers that link operational requirements to the design process is outlined and key concepts are identified. A format for documenting and selecting useful evaluation maneuvers is also described. Finally, the evaluation maneuvers and data demonstrating their sensitivity to design parameter variations are described.

This documentation is organized into a sequence of four reports. The first report, subtitled "Maneuver Development Process and Initial Maneuver Set," includes a detailed description of the research conducted as well as a summary of the results. It describes the maneuver development process used during this research and key considerations for developing new evaluation maneuvers. A brief summary of typical results observed for each maneuver tested is also included. The second report, subtitled "Maneuver Descriptions and Selection Guide," is a stand-alone document that describes the maneuvers tested during this research. It documents the intent of each maneuver, the aircraft attributes isolated, the techniques required to fly the maneuver, as well as presenting a cross reference to help select the most valuable maneuvers for aircraft evaluation. The second report is the beginning of a standard maneuver reference guide that will contain a wide variety of evaluation maneuvers for use throughout configuration development and flight test. It is recommended that new and existing evaluation maneuvers be added to this report to provide a source of evaluation maneuvers for the design and test community. The third report, subtitled "Simulation Data," consists of detailed information on the design parameter variations tested, subsequent statistical analyses conducted on the simulation data, and pilot comments and ratings from the testing. The fourth report, subtitled "Flight Test Plan," includes a preliminary test plan for the in-flight validation of the evaluation maneuvers.

Acknowledgments

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Nomenclature

ADI	Attitude Director Indicator
AOA	Angle Of Attack
CAP	Control Anticipation Parameter
CTOL	Conventional Takeoff and Landing
GLOC	g Induced Loss Of Consciousness
HARV	High Alpha Research Vehicle
HQDT	Handling Qualities During Tracking
HUD	Head-Up Display
IRAD	Internal Research and Development
MDA	McDonnell Douglas Aerospace
MuSIC	Multi-System Integrated Controls
PA	Power Approach
PIO	Pilot Induced Oscillation
PRR	Pitch Recovery Rating
S/MTD	STOL and Maneuvering Technology Demonstrator
STEMS	Standard Evaluation Maneuver Set
STOL	Short Takeoff and Landing

Chapter 1
Overview

The Standard Evaluation Maneuver Set (STEMS) is a collection of aircraft maneuvers that can be used to expose flying qualities and agility deficiencies as well as demonstrate capabilities in an operationally representative environment. STEMS maneuvers provide a link between the design of an aircraft and its operational use as shown in Figure 1. These maneuvers can be used to identify deficiencies while an aircraft is still in the design, development, or flight test stage rather than uncovering problems after a vehicle has entered operational use. They were not developed to compare an aircraft against specification parameters, but instead they provide a true evaluation of the flying qualities and agility of an aircraft in an operationally representative environment. These maneuvers also have been applied to the flight envelope expansion phase of flight test programs and could be used for aircraft-to-aircraft comparisons.

A key goal during the development of these maneuvers was to establish a link between operational requirements and the design process. This link ensures that the maneuvers can be used during the design process while emulating the dynamic requirements observed in an operational environment. This blends operational needs back into a repeatable, useful evaluation maneuver similar to the Handling Qualities During Tracking (HQDT) techniques.[1] By using an operationally relevant maneuver, the aircraft design can be evaluated in a fashion more like it will be used by the pilots. True operational relevance is somewhat unlikely for a maneuver that is intended to be repeatable and provide design guidance. However, the STEMS maneuvers are designed to require similar dynamic requirements to those needed during operational missions. This is what is meant by the term operationally relevant in this report.

The STEMS maneuvers allow the evaluation of a range of flying qualities and agility characteristics. Some maneuvers tend to isolate a single axis while others are multiple-axis tasks that are useful for evaluating harmony. The maneuvers vary from pure open-loop tasks to tight, closed-loop tracking tasks. The pilot technique ranges from structured (technique precisely defined) to unstructured (freestyle technique allowed). The best maneuver to use for a given evaluation depends upon the data and information of interest. Some maneuvers are more useful for qualitative data, whereas others are better suited for quantitative analyses. These characteristics are documented with each evaluation maneuver. A maneuver selection guide was developed to help the user choose potentially useful evaluation maneuvers. By using this guide, key maneuvers can be selected to evaluate the characteristics of interest, rather than testing all maneuvers.

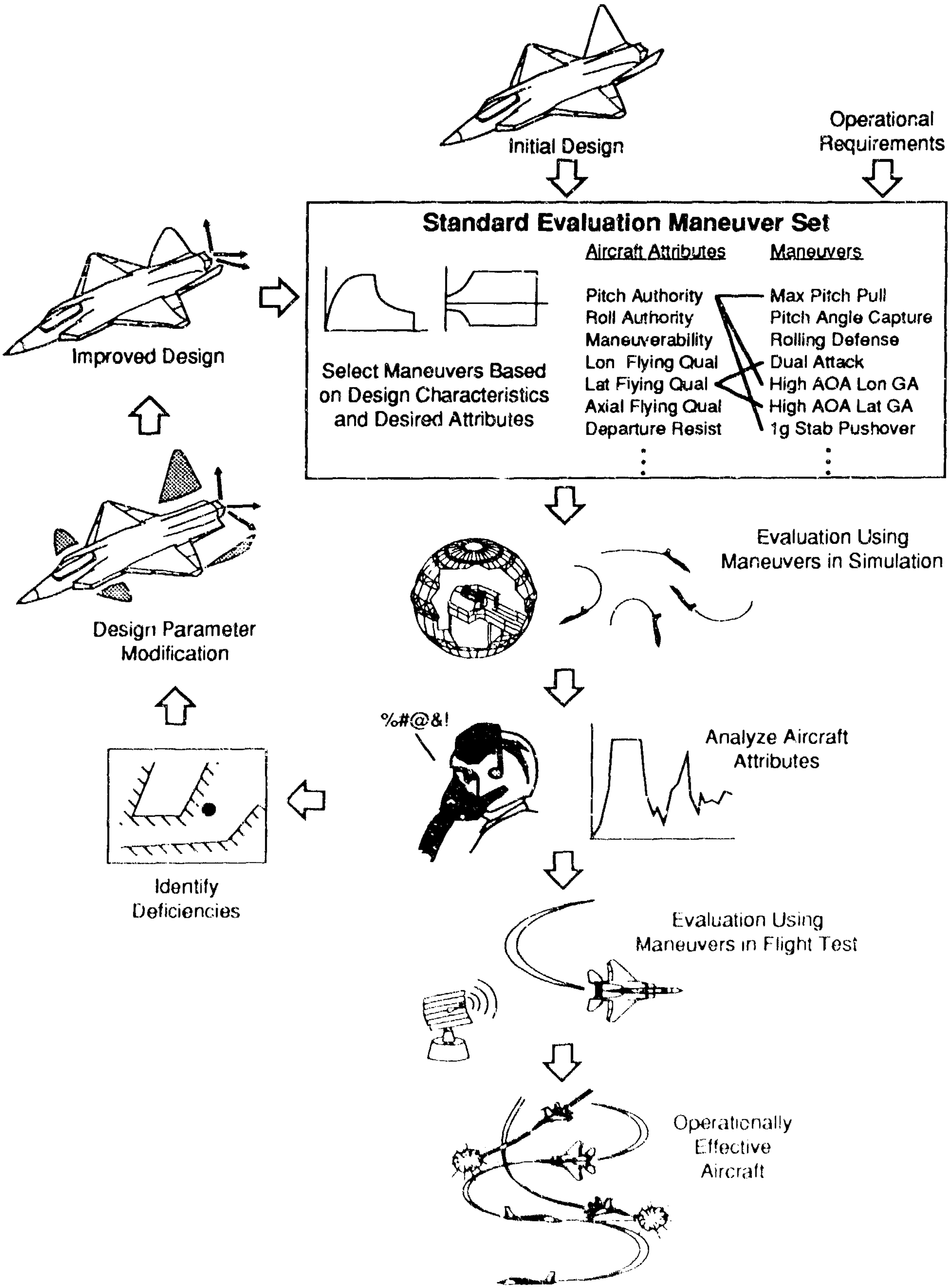


Figure 1. Evaluation Maneuvers Tie Operational Requirements to Design

Several of these maneuvers may be suitable for the development of design criteria or tactical utility studies. However, this research was not intended to be a criteria development effort or a tactical utility study. Instead, a sensitivity between each maneuver and various design parameters was established. Therefore, the designer now has an evaluation tool that can be used to measure changes in aircraft characteristics. Detailed simulation data for the initial 20 STEMS maneuvers is contained in Reference 2 and might be useful for future criteria development or tactical utility studies because it contains measure of merit data and pilot comments for numerous design parameter variations.

The Standard Evaluation Maneuver Set is intended to be a "living" document with periodic updates of additional evaluation maneuvers. Any additional maneuvers or experiences using STEMS should be forwarded to Wright Laboratory/FIGC_2, where the STEMS maneuver reference guide will be maintained and distributed. The initial set of maneuvers developed under the STEMS contract do not define a complete set of evaluation maneuvers. These maneuvers are meant to augment existing evaluation maneuvers. A much wider selection of maneuvers is required to evaluate an aircraft thoroughly. As a result, additional existing maneuvers, as well as new maneuvers, should be added to this document as they are developed. This will allow STEMS to be updated as new capabilities or technologies are developed.

This research also resulted in the definition of an effective and efficient maneuver development process so that additional maneuvers could be generated as the need arises. Such a process is desirable because this effort could not define a complete set of evaluation maneuvers. Instead it documents an initial set of standard maneuvers with the hope that others will continue to add useful evaluation maneuvers. Reference 3 contains a description of the recommended maneuver development process, a summary of the study used to generate the initial 20 evaluation maneuvers, and typical results for the maneuvers.

Some of the STEMS maneuvers have been validated with in-flight testing. However, a comprehensive flight test validation program is recommended and initial suggestions toward a flight test plan are presented in Reference 4. This flight test plan was written to help transition the experience obtained while developing these maneuvers in simulation to a flight test validation program. It is written generically so that it can be modified for any aircraft, but it is aimed towards aircraft with high angle of attack (AOA) capability.

This report is a stand-alone reference guide that contains the maneuver descriptions, a guide for the selection of maneuvers, and guidelines for the documentation of new evaluation maneuvers. Chapter 2 contains guidelines for the consistent documentation of evaluation maneuvers and describes terms and concepts necessary for the application of STEMS maneuvers. Chapter 3 includes a maneuver selection guide that can be used to help identify the best maneuvers for a particular application. Finally Chapter 4 contains descriptions of all of the STEMS maneuvers.

Chapter 2
Maneuver Documentation

A short maneuver description form has been designed to summarize evaluation maneuvers. This form is shown in Figure 2 and contains all of the key information required to understand and execute a maneuver. Only the most important information is contained on this page. Additional information can be included in narrative text that accompanies each maneuver. It may be beneficial to update and improve this maneuver description form over time, but it is recommended that a standard format continue to be used to document additional maneuvers.

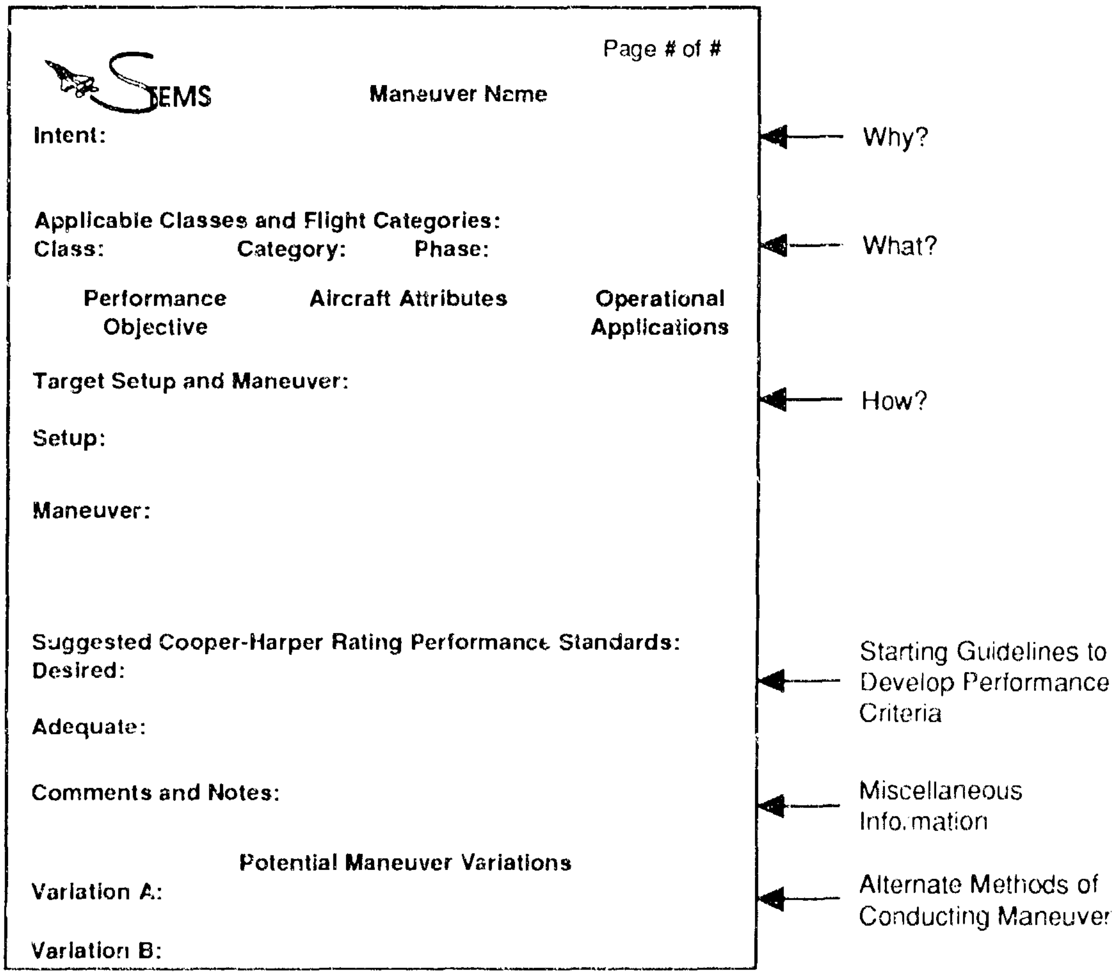


Figure 2. Maneuver Description Form

Maneuvers should be written generically so that they can be tailored to suit specific test objectives. They also may be modified based on configuration dependent placards, safety of flight issues, or unique capabilities. Additionally, specific setups may need to be altered based on the test aircraft performance capabilities (and target aircraft, if a target is required). The maneuver description form describes representative test conditions such as airspeed, altitude, and AOA, but the specific conditions to be tested are left to the evaluator. Multiple variations of the maneuver are also briefly described to show potentially useful alternative approaches such as testing throttle setting variations for configurations with thrust vectoring. In general, the maneuvers are structured so that they can be modified to best evaluate the specific aircraft and test objectives.

The features of the maneuver description form are shown in Figure 2. The various sections of the maneuver description form describe: 1) the reasons why the maneuver would be flown, 2) what type of attributes it measures, 3) the operational relevance of the maneuver, 4) how to set up and fly the maneuver, 5) guidelines on developing Cooper-Harper Rating[5] performance criteria, 6) important notes and comments about the maneuver, and 7) potential variations to the maneuver. A narrative description also accompanies each maneuver to document additional information not found on the maneuver description form. Each section of the maneuver description form is described below.

Maneuver Name

The maneuver name should be short and descriptive.

Intent

This is used to provide a brief description of why the maneuver should be used to evaluate an aircraft. It also contains a general statement of the type of data that can be expected from the maneuver.

Applicable Classes and Flight Categories

The type of aircraft that can be tested with the maneuver and the mission it is designed to evaluate are documented in this section. The aircraft classes and categories from the military flying qualities standard are used to provide a link to the information in MIL-STD-1797A.[6] The criteria and lessons learned in MIL-STD-1797A should be used in conjunction with STEMS.

Performance Objective

This block is used to describe the primary aircraft characteristic that is isolated by the maneuver and/or include a brief description of the performance attribute required to perform the task. Example entries include: "maintain adequate nose-down pitch control while rolling," "generate maximum pitch rates and sustain a high pitch rate through a large pitch angle change," "precisely track a target over a wide range of AOA," and "maintain pitch control and authority through a loop."

Aircraft Attributes

Brief phrases that describe the aircraft characteristics exhibited during the maneuver are included here. The list of attributes should define the primary attributes that are most strongly evaluated and can include some of the more important secondary attributes that are also observed during the maneuver. The attributes should be selected from a limited list so that the maneuvers can be effectively cross-referenced by their attributes. The list of aircraft attributes is intended to be a relatively short, manageable list. It should not include too specific attributes or it will become less useful as an index. For example, 30° AOA longitudinal flying qualities would be much too restrictive to be used effectively in a search. Figure 3 shows the current list of attributes which is adequate to describe the current evaluation maneuvers. Additional attributes may need to be added as more maneuvers are included in STEMS.

- Longitudinal Flying Qualities
- Lateral Flying Qualities
- Directional Flying Qualities
- Axial Flying Qualities
- Multi-Axis Flying Qualities
- Pitch Authority
- AOA Authority
- Roll Authority
- Pitch Control Margin
- Roll Coordination
- Pitch Performance
- Roll Performance
- Turn Performance
- Axial Performance
- Maneuverability
- PIO Tendencies
- Departure Resistance
- Frontside/Backside Operation

Figure 3 Current List of Aircraft Attributes

Operational Applications

A description of related operational maneuvers is included in this section. The dynamic characteristics and requirements of the evaluation maneuver should be similar to those experienced during training exercises or actual missions. The operational applications listed for a maneuver do not necessarily comprise an exhaustive list, but a few important examples are included to help describe the intent of the maneuver.

Target Setup and Maneuver

This section is only shown if a target aircraft is required to perform the maneuver. The initial conditions and relative geometry of the aircraft should be specified. If a sequence of maneuvers is recommended to establish the proper initial conditions, it can also be described here. Drawings are beneficial for more complex setups. The target trajectory and/or pilot inputs required to fly the proper path should also be described in this section. The target setup and maneuver may require some refinement by the user depending upon the performance characteristics of the aircraft.

Setup

The setup section is used to describe the initial position of the evaluation aircraft and/or any maneuvering required to establish the proper test conditions. Some maneuvers may require somewhat complex maneuvering to establish a necessary condition for data taking. Any part of the maneuver that is not intended for evaluation should be described in this section. Delineating the setup from the actual maneuver helps focus the evaluation on the intended characteristics.

Maneuver

The execution of the maneuver is detailed in this section. It should be worded as clearly as possible and specify any key requirements that the pilot must follow. If certain pilot techniques are required, they should be described. Capture tolerances should be recommended if a target (or parameter such as pitch attitude) is to be acquired during the maneuver. It may also be useful to test the aircraft using specific weapon systems and displays to evaluate the entire system. However, it is recommended that fixed reticle testing also be conducted to help isolate flying qualities deficiencies of the aircraft. Weapon launch requirements can also be used to judge performance during evaluation maneuvers that are very closely related to operational tasks.

Suggested Cooper-Harper Rating Performance Standards

This section indicates whether or not the maneuver is suitable for pilot ratings. The Cooper-Harper Rating scale[5] was not designed for open-loop tasks and should not be used for those maneuvers. Also, some closed-loop maneuvers may not be suitable for Cooper-Harper Ratings because of variability in the task or the use of multiple tasks in a single maneuver. Cooper-Harper Ratings may be attempted with these tasks, but the results must be treated cautiously and the pilot comments become even more critical. This section lists possible performance standards for maneuvers that are well suited for Cooper-Harper evaluations. These performance standards must be considered carefully because they can strongly influence the outcome of the evaluation. The performance criteria shown in this report are only suggestions and may be altered to suit the user's needs or test objectives better. When using a maneuver to develop new design criteria, it is important to clearly document the performance criteria used so that others can compare their results. Finally, it is important to maintain consistent performance criteria when comparing data to previously developed design criteria.

It is highly desirable to fit the above described sections onto a single page so that it can be a convenient and quick reference that summarizes key points of the maneuver. The following sections can be continued on the first page or be included on additional pages as necessary.

Comments and Notes

This section is used to list some important points to consider prior to flying the maneuver or modifying it for a specific test objective. A variety of information can be contained here, but should include only key points for emphasis. Additional details can be included with the narrative page that accompanies the maneuver. Any potential human factors concerns such as possible g induced Loss Of Consciousness (GLOC) or spatial disorientation should be listed here. Notes that describe the maneuver's sensitivity to initial conditions or references to additional sources of documentation on the maneuver can be included.

Potential Maneuver Variations

This section is used to describe maneuver variations that may also be tested (or tested in place of the primary description) depending upon test needs. Only the section(s) of the maneuver that are affected need to be shown (i.e. only the Setup section would be described if a variation was designed to alter the setup for flight test evaluations). Common variations include the flight condition and the power setting used during the evaluations. The power setting variations, for example, may be very important when testing an aircraft with thrust vectoring.

The maneuvers are loosely categorized as individual maneuvers, maneuver sequences, or freestyle maneuvers, Figure 4. It is difficult, as well as unnecessary, to strictly classify each maneuver as one of these types, since some maneuvers contain elements of each. However, these categories may be used as a general indicator of the nature of maneuver. Individual maneuvers are defined to be the most basic element of a maneuver, and they cannot be broken down further. Examples of individual maneuvers include the following: full stick pitch pull, nose-high pushover, and a 360° roll with no capture required. Maneuver sequences can be visualized as combinations of individual maneuvers. A pop-up ground attack maneuver can be thought of as a maneuver sequence because the pilot pulls to a desired pitch attitude, climbs to a given altitude, rolls inverted, pulls to and captures a target, then rolls back to wings level while tracking the target. As the name implies, freestyle maneuvers allow the pilot a great deal of freedom to fly the maneuver. Basically only the start and end conditions are specified for a freestyle maneuver. The pilot has the freedom to maneuver in any method to transition from one state to the other state. An example freestyle maneuver would be a minimum time 180° heading change where the pilot is allowed to try a variety of tactics.

The advantage of classifying a maneuver is that it assists in defining the pilot techniques allowed and helps determine the type of data analysis that can be conducted. Individual maneuvers are generally best to gather quantitative data because they contain less variability. They are developed to isolate a single task and as a result they tend to be simpler and more repeatable. Maneuver sequences are usually more complex to analyze. They are composed of several tasks, each of which often depends upon the outcome of the previous task. As a result, it may be more useful to see how a configuration transitions between tasks rather than measuring the overall outcome. High quality quantitative data tends to be more difficult to obtain from maneuver sequences because of the added variability. Freestyle maneuvers result in much better qualitative data than quantitative data and even the qualitative data may be difficult to use for design guidance. The freestyle maneuvers may be best suited for demonstrating unique capabilities of an aircraft and comparing various techniques to perform a maneuver objective. Freestyle maneuvers may also be useful to test a configuration over a wider range of flight conditions, aircraft states, and pilot inputs.

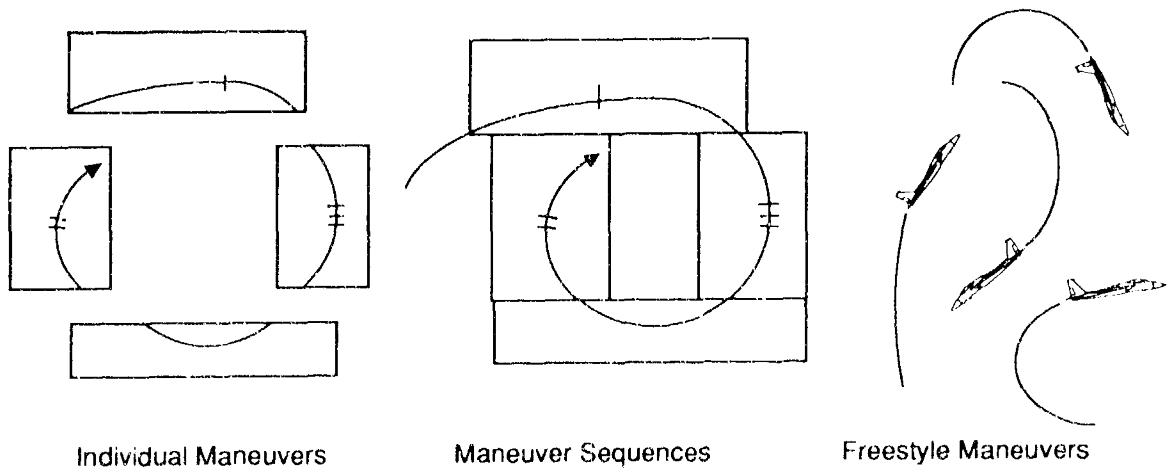


Figure 4. Maneuvers Can Generally Be Classified Into Three Categories

Chapter 3
Maneuver Selection Guide

A maneuver selection guide is included in this section to help the user choose evaluation maneuvers that best suit specific aircraft and test objectives. Cross reference tables are included to help the user review general characteristics of each maneuver and isolate maneuvers that have been used to evaluate specific design parameters. Additional cross reference tables are included to help find all of the maneuvers that expose a particular aircraft attribute. These cross references can be consulted to select potential evaluation maneuvers. The maneuver description sheets and accompanying narrative text then can be further examined to determine the best maneuvers for specific test objectives. In particular, additional information listed in the Intent, Performance Objective, and Operational Application sections of each maneuver description form can be reviewed to help make the final maneuver selection.

General characteristics of the STEMS maneuvers have been identified and are shown in Figure 5. This chart can be used to help screen for potentially useful evaluation maneuvers based on specific aircraft characteristics and test objectives such as flight envelope, axis, and data required. Five major categories are shown on this figure including: applicable flight envelope, primary evaluation axis, data type generated, precision required, and maneuver type. These categories are intended to help guide the user to select maneuvers that are most closely aligned with specific test needs. More than one check mark may appear in each category for certain maneuvers indicating a wide range of applicability. For instance, some maneuvers may be valid to apply in the conventional envelope as well as at high AOA. Also, some maneuvers may require a segment of moderate precision as well as tight control or may contain shades of an individual maneuver and a maneuver sequence.

A table of key design parameters and the maneuvers that have been used to successfully evaluate them is shown in Figure 6. This table can be used if a designer wants to evaluate the effects of altering a specific design parameter. This table repeats the quantitative/qualitative data column found in Figure 5 so that the user knows whether to expect numerical data or pilot comments from each maneuver. The check marks indicate maneuvers that were found to be sensitive to variations in specific design parameters and the letter "N" is used to indicated cases that were found to not be sensitive. Combinations without a check mark or "N" simply indicate a lack of test data for evaluation. The design parameters in Figure 6 do not represent an exhaustive list. Therefore, additional testing to further complete this table is highly recommended. Test experience with any of the STEMS maneuvers should be sent to Wright Laboratory/FIGC_2 so that this table can be expanded and improved for future use.

A final maneuver cross reference is included in this section to help screen for potentially useful evaluation maneuvers. Figure 7 shows each of the aircraft attributes and lists all of the maneuvers that can be used to isolate that attribute. This cross reference can be used when planning a test to evaluate a specific attribute or to ensure that a wide range of aircraft characteristics are considered. This attribute cross reference should also be updated as new maneuvers are added to STEMS.

	Env.		Axis			Data		Precision				Type		
Maneuver Number and Name	**Conventional**	**High AOA**	**Longitudinal**	**Lateral-Directional**	**Axial**	**Quantitative**	**Qualitative**	**No Capture**	**Gross Capture**	**Moderate**	**Tight Control**	**Individual Maneuver**	**Maneuver Sequence**	**Freestyle Maneuver**
1. Tracking During High AOA Sweep		√	√	√			√				√	√		
2. High AOA Tracking		√	√	√			√				√	√		
3. High AOA Lateral Gross Acquisition		√		√		√	√			√		√	√	
4. Dual Attack	√	√	√	√			√			√	√		√	√
5. Rolling Defense		√	√	√		√		√				√		
6. Maximum Pitch Pull	√	√	√			√		√				√		
7. Nose-Up Pitch Angle Capture	√	√	√			√	√			√		√	√	
8. Crossing Target Acq. and Tracking	√	√	√	√			√			√	√		√	√
9. Pitch Rate Reserve		√	√			√		√				√		
10. High AOA Longitudinal Gross Acq.		√	√			√	√			√		√	√	
11. Sharkenhausen	√	√	√	√		√	√			√	√			√
12. High AOA Roll Reversal		√		√		√		√				√	√	
13. High AOA Roll and Capture		√		√		√	√			√		√	√	
14. Minimum Speed Full Stick Loop	√	√	√		√		√	√					√	
15. Minimum Time 180° Heading Change	√	√	√	√	√		√		√					√
16. 1-g Stabilized Pushover		√	√			√		√				√		
17. J-Turn		√	√	√			√		√				√	
18. Tanker Boom Tracking	√		√	√	√		√			√	√	√		
19. Tracking in Power Approach	√		√	√	√		√			√	√	√	√	
20. Offset Approach to Landing	√		√	√	√		√			√	√	√	√	

Figure 5. General Characteristics of STEMS Maneuvers

	Data		Design Parameters															
Maneuver Number and Name	**Quantitative**	**Qualitative**	**Short Period Freq. (Includes CAP)**	**Short Period Damping**	**Maximum ACA**	**Longitudinal Stick Sensitivity**	**Longitudinal Stick Shaping**	**Lon. Command Type**	**CG Location**	**Longitudinal Dynamics†**	**Maximum Roll Rate**	**Roll Time Constant**	**Roll Acceleration Limiter**	**Lateral Dynamics†**	**Engine Time Constant**	**Time Delay**	**Thrust Vectoring Engaged/Disengaged**	**Vectoring Rate Limits**
1. Tracking During High AOA Sweep		√	√	√							√	√						
2. High AOA Tracking		√	√	√							√	√						
3. High AOA Lateral Gross Acquisition	√	√									√	√						√
4. Dual Attack		√			√					√				√				√
5. Rolling Defense	√								√		√							
6. Maximum Pitch Pull	√		√	√	√													
7. Nose-Up Pitch Angle Capture	√	√	√	√		√	√									N		
8. Crossing Target Acq. and Tracking		√	√								√	√						
9. Pitch Rate Reserve	√		√	√	√	N												
10. High AOA Longitudinal Gross Acq.	√	√	√	√														√
11. Sharkenhausen	√	√			√					√				√				
12. High AOA Roll Reversal	√										√	√	√					
13. High AOA Roll and Capture	√	√									√	√						
14. Minimum Speed Full Stick Loop		√															√	
15. Minimum Time 180° Heading Change		√															√	
16. 1-g Stabilized Pushover	√								√									
17. J-Turn		√	√					√			√						√	
18. Tanker Boom Tracking		√	√	√								√						
19. Tracking in Power Approach		√	√	√							√	√						
20. Offset Approach to Landing		√	√	√							√	√			√	N		

√ Design Parameter Successfully Tested

N Design Parameter Not Successfully Tested

† Longitudinal Dynamics Indicates a Combination of Frequency and Damping Tested; Lateral Dynamics Indicates a Combination of Roll Mode Time Constant and Maximum Roll Rate

Figure 6. Design Parameters Evaluated With STEMS Maneuvers

Longitudinal Flying Qualities

1 Tracking During High AOA Sweep
2 High AOA Tracking
4 Dual Attack
7 Nose-Up Pitch Angle Capture
8 Crossing Target Acq and Track
10 High AOA Lon Gross Acquisition
11 Sharkenhausen
18 Tanker Boom Tracking
19 Tracking in PA
20 Offset Approach to Landing

Lateral Flying Qualities

1 Tracking During High AOA Sweep
2 High AOA Tracking
3 High AOA Lateral Gross Acquisition
4 Dual Attack
8 Crossing Target Acq and Track
11 Sharkenhausen
13 High AOA Roll and Capture
18 Tanker Boom Tracking
19 Tracking in PA
20 Offset Approach to Landing

Directional Flying Qualities

1 Tracking During High AOA Sweep
2 High AOA Tracking
4 Dual Attack
8 Crossing Target Acq and Track
11 Sharkenhausen
18 Tanker Boom Tracking
19 Tracking in PA
20 Offset Approach to Landing

Axial Flying Qualities

18 Tanker Boom Tracking
19 Tracking in PA
20 Offset Approach to Landing

Multi-Axis Flying Qualities

1 Tracking During High AOA Sweep
4 Dual Attack
8 Crossing Target Acq and Track
11 Sharkenhausen
18 Tanker Boom Tracking
19 Tracking in PA
20 Offset Approach to Landing

Pitch Authority

5 Rolling Defense
6 Maximum Pitch Pull
9 Pitch Rate Reserve
14 Minimum Speed Full Stick Loop
16 1-g Stabilized Pushover
17 J-turn

Roll Authority

5 Rolling Defense
12 High AOA Roll Reversal
17 J-turn

Pitch Control Margin

5 Rolling Defense
16 1-g Stabilized Pushover

Roll Coordination

5 Rolling Defense
12 High AOA Roll Reversal
13 High AOA Roll and Capture

Pitch Performance

4 Dual Attack
7 Nose-Up Pitch Angle Capture
8 Crossing Target Acq and Track
9 Pitch Rate Reserve
10 High AOA Lon Gross Acquisition
11 Sharkenhausen
15 Minimum Time 180° Heading Change
16 1-g Stabilized Pushover
17 J-turn

Figure 7. Maneuver Cross Reference by Aircraft Attributes

Roll Performance

3 High AOA Lateral Gross Acquisition
4 Dual Attack
8 Crossing Target Acq and Track
11 Sharkenhausen
12 High AOA Roll Reversal
13 High AOA Roll and Capture
14 Minimum Speed Full Stick Loop
15 Minimum Time 180° Heading Change
17 J-turn

Turn Performance

4 Dual Attack
8 Crossing Target Acq and Tracking
9 Pitch Rate Reserve
11 Sharkenhausen
14 Minimum Speed Full Stick Loop

Axial Performance

14 Minimum Speed Full Stick Loop
15 Minimum Time 180° Heading Change

Maneuverability

6 Maximum Pitch Pull
7 Nose-Up Pitch Angle Capture
9 Pitch Rate Reserve
11 Sharkenhausen
14 Minimum Speed Full Stick Loop
15 Minimum Time 180° Heading Change
20 Offset Approach to Landing

PIO Tendencies

1 Tracking During High AOA Sweep
2 High AOA Tracking
3 High AOA Lateral Gross Acquisition
7 Nose-Up Pitch Angle Capture
8 Crossing Target Acq and Track
10 High AOA Lon Gross Acquisition
11 Sharkenhausen
18 Tanker Boom Tracking
20 Offset Approach to Landing

Departure Resistance

5 Rolling Defense
6 Maximum Pitch Pull
9 Pitch Rate Reserve
12 High AOA Roll Reversal
14 Minimum Speed Full Stick Loop

Frontside/Backside Operation

19 Tracking in PA
20 Offset Approach to Landing

Figure 7. Maneuver Cross Reference by Aircraft Attributes (Cont)

Chapter 4
Evaluation Maneuver Descriptions

This section contains the standard evaluation maneuvers. Maneuver description sheets and additional narrative with supporting information are included. Many of the high AOA maneuvers could be departure prone depending upon the particular aircraft being evaluated. Therefore they require that envelope expansion testing be completed prior to evaluation, or they can be conducted in a build-up fashion as part of an envelope expansion effort. It is recommended that the STEMS maneuvers be reviewed and potentially modified prior to flight based on each aircraft's unique characteristics. Details such as desired test airspeed, angle of attack, throttle setting, etc. should be specified according to the test objectives.

STEM 1: Tracking During High AOA Sweep

Tracking During High AOA Sweep is a good maneuver to evaluate longitudinal, lateral, and directional precision flying qualities over a wide AOA range. This task allows the evaluation of spot tracking capabilities and the ability to make aim point corrections. This maneuver also has a strong link to operational requirements and is a direct extension of the Handling Qualities During Tracking (HQDT) technique.[1] It can be used to evaluate tracking over a wide AOA range and identify potential problem areas. If any problems are uncovered, the High AOA Tracking maneuver (STEM 2) can be used to isolate an AOA for closer investigation. Pilot comments constitute the primary source of data. Pilot ratings were taken during simulation, but the comments proved to be much more valuable since the pilot is evaluating such a wide range of AOA and a variety of axes. This maneuver does not tend to generate good quantitative measure of merit data because of the closed-loop nature of the task. The Tracking During High AOA Sweep was successfully used to evaluate variations in roll sensitivity, roll mode time constant, short period frequency, and short period damping.

STEMS

STEM 1: Tracking During High AOA Sweep

Intent:
This maneuver allows an evaluation of the tracking capabilities of an aircraft over a wide range of AOA. It is intended to be used to isolate potential tracking problems that can be studied in more detail with a stabilized tracking task. This maneuver generates qualitative data.

Applicable Classes and Flight Categories:
Class: IV **Category:** A **Phase:** CO

Performance Objective	Aircraft Attributes	Operational Applications
Precisely track a target over a wide range of AOA.	Longitudinal flying qualities Lateral flying qualities Directional flying qualities Multi-axis flying qualities AOA authority PIO tendencies	Stabilized guns tracking Minimum range boresight tracking

Target Setup and Maneuver:
The target begins co-speed with the evaluation aircraft at approximately 350 KCAS. The target enters a descending constant g turn (2500 fpm, 4g).

Setup:
The test aircraft begins directly in trail of the target. The test aircraft follows the target in a pure pursuit guns track, adjusting power to allow a slow AOA build up until tracking can no longer be maintained.

Maneuver:
Two evaluations can be conducted. The first is to evaluate spot tracking capability and the second is to evaluate the ability to make rapid aim point changes on the target. During the point tracking evaluation, use a fixed 10 mil diameter reticle, noting changes in flying qualities over the full AOA range. During the aim point recorrection evaluation, perform single axis repositions (of approximately 50 mils) to acquire and track while using a fixed 50 mil reticle. Perform repositions in each axis every 5° or 10° AOA.

Suggested Cooper-Harper Rating Performance Standards:
For the point tracking task:

Desired: No PIO. Pipper within ±5 mils of aim point 50% of the task and within ±25 mils the remainder of the task.

Adequate: Pipper within ±5 mils of aim point 10% of the task and within ±25 mils the remainder of the task.

For the aim point correction task:

Desired: Aggressively acquire aim point within the 50 mil reticle with no more than 1 overshoot and within desired time.

Adequate: Aggressively acquire aim point within the 50 mil reticle with no more than 2 overshoots and within adequate time.

STEMS

STEM 1: Tracking During High AOA Sweep

Comments and Notes:

1. This STEM is recommended to assist in the discovery of AOA ranges where potential tracking deficiencies may occur. A more extensive tracking evaluation can then be conducted using STEM 2.

2. The target profile may need to be modified based on aircraft performance. The maneuver can best be modified in simulation prior to flight testing. The target load factor and descent rate can be varied depending on the performance capabilities of both aircraft.

Potential Maneuver Variations

Variation A:
Maneuver:
The pilot can stabilize at 5° AOA increments rather than flying a smooth AOA sweep. This can be done as long as enough excess energy is available. This allows an extended tracking evaluation.

Variation B:
Maneuver:
The pilot can potentially combine the tracking and reposition evaluations into one test. However depending on the test aircraft and target aircraft performance characteristics, the pilot may not have adequate evaluation time.

STEM 2: High AOA Tracking

The High AOA Tracking maneuver was developed and extensively tested under McDonnell Douglas Aerospace (MDA) Internal Research and Development (IRAD)[7-9] and NASA sponsored[10,11] research. Specific variations of this maneuver were defined and tested at 30°, 45°, and 60° angle of attack under NASA and MDA efforts. Detailed maneuver descriptions can be found in References 8, 10, and 11 for each AOA tested. A general description, that can be modified to a wide range of AOA, is shown on the maneuver description sheet. Specific test conditions for 30°, 45°, and 60° AOA are shown in the Variations section. This maneuver is designed to isolate the tracking characteristics at a specific AOA and allow a piloted evaluation of the spot tracking and aim point correction capabilities. It can be used to isolate an axis or evaluate multi-axis capabilities in the longitudinal, lateral, and directional axes. The Tracking During High AOA Sweep maneuver (STEM 1) can be an effective maneuver to expose potential problems initially. This maneuver can then be used to thoroughly evaluate a specific condition or axis. Pilot comments constitute the primary data source. Ratings have been used successfully to develop flying qualities criteria for a range of post-stall AOA.[8-11] This maneuver should not be used to generate quantitative measures of merit because of its closed-loop nature. This maneuver has been successfully used to evaluate variations in roll sensitivity, roll mode time constant, short period frequency, and short period damping. Testing has been conducted on aircraft models with AOA, AOA rate, pitch rate, and blended longitudinal axis command systems. The High AOA Tracking maneuver was successfully tested in flight during an Air Force Test Pilot School class project;[12] however, this testing was at low to moderate AOA. This maneuver has also been flown on the NASA High Alpha Research Vehicle (HARV) at higher angles of attack.

STEMS

STEM 2: High AOA Tracking

Intent:
This maneuver is intended to expose tracking flying qualities characteristics at high AOA for a single axis. A combination of precise tracking and small aim point corrections are used to evaluate tracking at a specific angle of attack. This maneuver generates qualitative data.

Applicable Classes and Flight Categories:
Class: IV **Category:** A **Phase:** CO

Performance Objective	Aircraft Attributes	Operational Applications
Precisely track a target at high AOA.	Longitudinal flying qualities Lateral flying qualities Directional flying qualities PIO tendencies	Stabilized guns tracking Minimum range boresight tracking

Target Setup and Maneuver:
Target aggressively rolls and pulls to establish a constant AOA descending turn. The target then adjusts bank angle to maintain a predetermined airspeed.

Setup:
The test aircraft begins in 1-g level flight approximately 1500 ft directly behind the target aircraft. Both aircraft begin co-speed and co-heading. After the target rolls into a turn, the evaluation pilot should roll in behind the target and go to a lag position. The pilot can then gradually pull to a stabilized tracking position at the test AOA.

Maneuver:
The pilot should evaluate the ability to tightly track a point on the target and conduct 50 mil aim point corrections on the target. Separate evaluations of the longitudinal and lateral axes should be conducted if possible. Throttle changes may be required to approximately maintain the test AOA. When AOA exceeds a desired range, break off the task and try to regain a stabilized tracking position at the test AOA.

Suggested Cooper-Harper Rating Performance Standards:

Desired: No PIO. Pipper within ±5 mils of aim point 50% of the task and within ±25 mils the remainder of the task.

Adequate: Pipper within ±5 mils of aim point 10% of the task and within ±25 mils the remainder of the task.

Comments and Notes:

1. This maneuver was developed and tested under another effort. The general maneuver description is given here. Specific maneuvers were developed for 30°, 45°, and 60° AOA. The 30° and 45° AOA tasks are described in detail in NASA CR-4435, "Flying Qualities Criteria Development Through Manned Simulation for 45° Angle of Attack - Final Report" and the 60° AOA task is described in "Flying Qualities Criteria Development for 60° Angle of Attack" (a NASA CR to be published in 1993).

STEMS

STEM 2: High AOA Tracking

Potential Maneuver Variations

Variation A: (Specifics required for 30° AOA testing, F/A-18 target, HARV evaluation)
Target Setup and Maneuver:
Target starts at M=0.5, H=25000 ft. Target rolls and pulls to establish a descending turn at 25° AOA and tries to maintain 160 kt.

Variation B: (Specifics required for 45° and 60° AOA testing, F/A-18 target, HARV evaluation)
Target Setup and Maneuver:
Target starts at M=0.5, H=25000 ft. Target rolls and pulls to establish a descending turn at 30° AOA and tries to maintain 160 kt.

STEM 3: High AOA Lateral Gross Acquisition

The High AOA Lateral Gross Acquisition maneuver was developed and extensively tested under MDA IRAD[7,8] and NASA sponsored[10,11] research. Specific variations of this maneuver were defined and tested at 30°, 45°, and 60° AOA under the NASA and MDA efforts. Detailed maneuver descriptions can be found in References 8, 10, and 11 for each AOA tested. A general description, that can be modified to a wide range of AOA, is shown on the maneuver description sheet. Specific test conditions for 30°, 45°, and 60° AOA are shown in the Variations section. It can be used to isolate the high AOA lateral acquisition flying qualities of a configuration at a specific AOA. Specifically, the controllability of the capture and the roll rate achieved (or time to complete the task) can be evaluated during this task. Pilot comments and ratings are the primary data generated from this maneuver. Data generated using this maneuver has been used to develop flying qualities criteria for various angles of attack.[8,10,11] Measure of merit data may also be obtained with this maneuver, though it is primarily intended as a flying qualities evaluation. Analyses conducted under NASA research have shown some interesting correlations between measure of merit analyses and flying qualities criteria boundaries.[11] This maneuver has been used to evaluate variations in maximum roll rate, roll mode time constant, and thrust vectoring nozzle rate capabilities. This maneuver was found to be flyable using aircraft with AOA and pitch rate longitudinal command systems. The High AOA Lateral Gross Acquisition maneuver was tested in flight during an Air Force Test Pilot School project;[12] however, this testing was at low to moderate AOA. The maneuver was also flown to evaluate high AOA roll capabilities of the X-29 and is planned for evaluations of the HARV.

STEMS

STEM 3: High AOA Lateral Gross Acquisition

Intent:
This maneuver is intended to isolate the flying qualities characteristics of an aircraft during a high AOA lateral capture task. The data generated is primarily qualitative in nature but some quantitative data may also be obtained.

Applicable Classes and Flight Categories:
Class: IV **Category:** A **Phase:** CO

Performance Objective	Aircraft Attributes	Operational Applications
Conduct a high AOA gross acquisition of a target aircraft.	Lateral flying qualities Roll performance PIO tendencies	Shift targets Turn reversal Weapons acquisition Nose intimidation

Target Setup and Maneuver:
The target rolls and pulls to establish a constant AOA descending turn. The target then adjusts bank angle to maintain a predetermined airspeed.

Setup:
The test aircraft begins in 1-g level flight approximately 1500 ft behind and 1000 ft below the target aircraft. When the target rolls, hesitate until target is approximately 10° to 20° off of nose (depends upon the test AOA and aircraft lateral dynamics). Quickly pull to the test AOA and advance throttles to the desired test setting. Hesitate momentarily (the length of hesitation will depend upon the roll performance of the test aircraft and should be timed such that the roll and capture can occur at a relatively constant AOA).

Maneuver:
After setting the test AOA and hesitating momentarily, aggressively roll to capture target. Initiation of the roll actually defines the beginning of the measurement portion of the maneuver. Maintain test AOA during roll. Aggressively acquire the target within an 80 mil vertical band (or reticle). Limit evaluation to lateral axis as much as possible. (Target can be captured slightly above or below the reticle to try to maintain test AOA.)

Suggested Cooper-Harper Rating Performance Standards:

Desired: Aggressively acquire aim point within 80 mils laterally with no more than 1 lateral overshoot and within a desired time to accomplish the task.

Adequate: Aggressively acquire aim point within 80 mils laterally with no more than 2 lateral overshoots and within an adequate time to accomplish the task.

STEMS

STEM 3: High AOA Lateral Gross Acquisition

Comments and Notes:

1. A general maneuver description is given here. Specific maneuvers were developed for 30°, 45°, and 60° AOA. T 45° AOA tasks are described in detail in NASA CR-4435, "Flying Qualities Criteria Development Through Manne Simulation for 45° Angle of Attack - Final Report" and the 60° AOA task is described in "Flying Qualities Criteria Development for 60° Angle of Attack" (a NASA CR to be published in 1993).

2. It is very beneficial to conduct training in a simulator for this maneuver prior to flight testing.

3. The desired and adequate time referenced in the Cooper-Harper performance standards can be left vague to try to identify an operationally meaningful time from the piloted data. The performance criteria times car strictly defined to reduce variability. The work presented in "Flying Qualities Criteria Development for 60° Angle c indicates that 3.5 sec correlated with the pilots perception of desired time to perform this task at 60° AOA and 6.5 with adequate time.

4. Maneuver should be flown at several different target AOAs.

5. Various throttle settings can be tested.

Potential Maneuver Variations

Variation A: (Specifics required for 30° AOA testing, F/A-18 target, HARV evaluation)
Target Setup and Maneuver:
Target starts at M=0.45, H=25000 ft. Target rolls and pulls to establisn a descending turn at 30° AOA and tries to maintain 160-180 kt.

Variation B: (Specifics required for 45° and 60° AOA testing, F/A-18 target, HARV evaluation)
Target Setup and Maneuver:
Target starts at M=0.5, H=25000 ft. Target rolls and pulls to establish a descending turn at 30° AOA and tries to maintain 160-180 kt.

STEM 4: Dual Attack

The Dual Attack maneuver is an operationally relevant task that is excellent for demonstrating the benefits of high AOA roll capability or comparing two aircraft with different high AOA capabilities. It is also a useful evaluation maneuver to verify multi-axis flying qualities over a wide maneuvering envelope. It simulates a multi-target engagement where high AOA acquisition and tracking capabilities are needed. The maneuver can be flown using a loaded roll technique between the two targets or an unload, roll, and pull technique to compare aircraft with varying levels of high AOA roll authority. Variation D of this maneuver is extremely useful to extend the length of the evaluation and provide a wider variety of target acquisitions. This variation can also result in very nose high evaluations after the targets turn back toward the test aircraft because the targets tend to maintain a constant altitude while the test aircraft continues to descend in altitude throughout the maneuver. The maneuver results in much better qualitative data than quantitative. Pilot comments are the primary source of evaluation data. Pilot ratings were not taken due to the unstructured nature of the task. Results from this maneuver can be sensitive to pilot technique. The relative offset to the second target becomes larger as the time required to capture the first target increases. This results in poor numerical measures of merit but produces a good qualitative evaluation because some predictability is removed; therefore, it is difficult to "game" the task. This maneuver has been used to demonstrate the effects of maximum AOA authority, variations in longitudinal and lateral dynamics, benefits of adding thrust vectoring, and vectoring nozzle rate limits. The Dual Attack maneuver has been used to evaluate aircraft with AOA and blended rate command systems in the longitudinal axis.

STEMS

STEM 4: Dual Attack

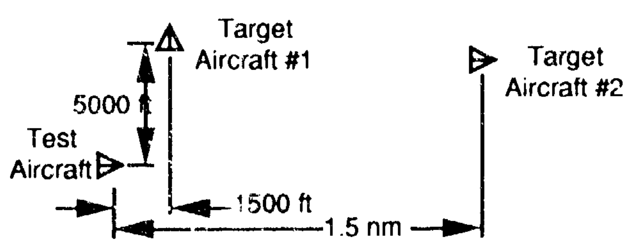
Intent:
This maneuver is intended to exercise the acquisition capabilities of an aircraft through rapid multiple-axis acquisitions of two target aircraft. The ability to reach high angles of attack and subsequently control the aircraft is highlighted. The advantages of good high angle of attack roll performance can be demonstrated.

Applicable Classes and Flight Categories:
Class: IV **Category:** A **Phase:** CO

Performance Objective	Aircraft Attributes	Operational Applications
Conduct a gross acquisition of a target aircraft and then rapidly maneuver to conduct a gross acquisition of a second target.	Roll performance Pitch performance Turn performance Longitudinal flying qualities Lateral flying qualities Directional flying qualities Multi-axis flying qualities	Minimum time to attack 2 aircraft

Target Setup and Maneuver:
Initial positions of target aircraft are described below. Both target aircraft maintain constant speed, straight and level flight during the maneuver.

Setup:
All aircraft begin co-speed at Vmin and in straight and level flight as shown below.



Maneuver:
Maneuver to capture Target Aircraft #1 within an 80 mil reticle in minimum time. Hold target aircraft #1 in the reticle for 2 continuous seconds and then perform a loaded roll to maneuver toward the second target. Capture target aircraft #2 within an 80 mil reticle for 2 seconds. The test aircraft can continue to reverse between target #1 and target #2 with each reversal covering a larger angular offset.

Suggested Cooper-Harper Rating Performance Standards:
It is not recommended to use the Cooper-Harper rating scale with this maneuver.

Comments and Notes:
1. The 5000 ft offset between the test and target aircraft may need to be varied depending on the test aircraft turn performance.

2. An alternate setup was also tested in simulation. This setup is described as Variation C and should be easier to establish during flight test.

3. A captive missile can be used to indicate a valid capture on a target. When the pilot gets the tone on an aircraft, he can immediately uncage the missile and simulate launch, then acquire and fire on the other target. This may add additional variability, but it enhances realism.

Potential Maneuver Variations

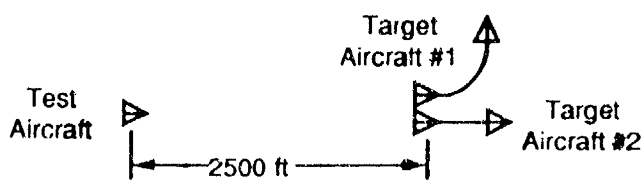
Variation A:
Maneuver:
Three techniques can be tested when maneuvering from Target Aircraft #1 to #2. The maneuver description calls for a loaded roll between targets #1 and #2 to emphasize the evaluation of high AOA roll performance. An unloaded roll and pull to the second target can be used to emphasize pitch performance and to directly compare with the loaded roll technique. Finally the pilot can be allowed a freestyle evaluation of the maneuver; however, this will probably not differ significantly from the loaded or unloaded technique.

Variation B:
Setup:
The following airspeeds can be tested to cover a range of aircraft characteristics:
Vmin, (Vmin+Vc)/2, Vc

Variation C:
An alternate task setup, which should be easier to establish in flight test, was defined through simulation:

Target Setup and Maneuver:
Two targets begin abreast, approximately 2000-2500 ft ahead of the test aircraft. Both target aircraft maintain constant speed during the maneuver. Target #2 maintains straight and level flight while target #1 makes an initial 90° turn to the left and then maintains straight and level flight.

Setup:
All aircraft begin co-speed at Vmin and in straight and level flight as shown below.

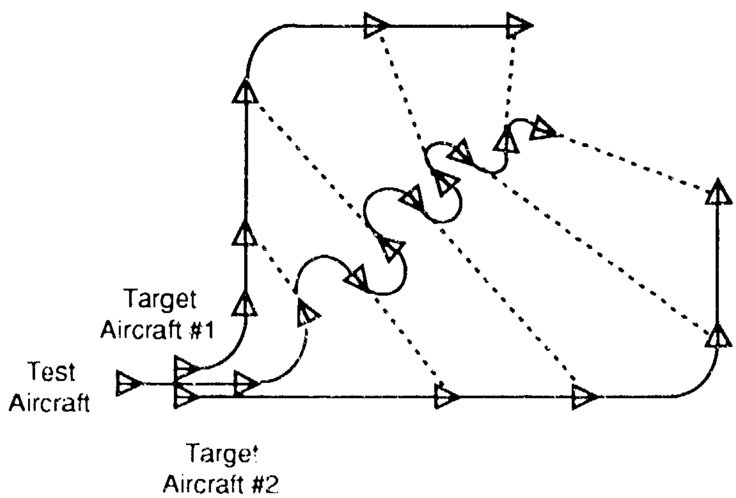


Maneuver:
After target #1 executes a turn, maintain straight and level flight. When target #1 reaches the test aircraft's 3 o'clock position, aggressively maneuver to capture target #1 within an 80 mil reticle in minimum time. Hold target #1 in the reticle for 2 continuous seconds and then perform a loaded roll to maneuver toward the second target. Capture target #2 within an 80 mil reticle for 2 seconds. The test aircraft can continue to reverse between target #1 and target #2 with each reversal covering a larger angular offset.

STEMS

STEM 4: Dual Attack

Variation D:
The length and usefulness of this maneuver can be extended by allowing the targets to turn back toward the test aircraft after the range to target has become large. This enables additional acquisitions to be performed by avoiding visual loss of the targets. It is also convenient to bring the aircraft back together for the next setup. The number of acquisitions that can be accomplished before the targets turn back in depends upon the speed at which the maneuver is being conducted and the test aircraft characteristics. Range between the test and target aircraft should probably be used to determine when to have the targets turn. The illustration below demonstrates a sequence of maneuvering.



STEM 5: Rolling Defense

The Rolling Defense maneuver enables the evaluation of nose-down control power remaining while performing a roll. It has limited operational application -- it is specifically designed to evaluate the aircraft control law inertia coupling compensation. It also demonstrates the maximum roll performance of an aircraft. It should be conducted at various angles of attack to check combinations of maximum roll rate capability and nose-down control power. This maneuver generates primarily quantitative data. Time history data can be used to evaluate control law gains and surface rate and position limits. Some pilot comments may result, but the dynamic nature of the task makes it a difficult one on which to comment. This maneuver requires additional practice because of the somewhat complex setup. During simulation it was successfully used to show differences in maximum roll rate and nose down control power. It has also been demonstrated in flight at moderate AOA as part of an Air Force Test Pilot School project.[13]

STEMS

STEM 5: Rolling Defense

Intent:
This maneuver is primarily intended as a control law evaluation to verify the nose-down pitch authority remaining while in a rolling condition. Additional information about roll coordination and maximum roll rate may also be obtained. This maneuver primarily generates quantitative data but may also provide some pilot comments.

Applicable Classes and Flight Categories:
Class: IV **Category:** A **Phase:** CO

Performance Objective	Aircraft Attributes	Operational Applications
Maintain adequate nose-down pitch control while rolling.	Pitch authority Pitch control margin Departure resistance Roll coordination Roll authority	Guns defense Collision avoidance

Setup:
Begin maneuver above test airspeed. Initiate a level turn to achieve test AOA. Select desired power setting. As speed decays, maintain AOA and bank angle for level turn. When airspeed reaches test value, apply full roll controls (roll over the top) to reverse angle of bank while maintaining target AOA.

Maneuver:
As soon as aircraft passes through the opposite 90° bank angle, apply full forward stick while maintaining full roll controls. Maneuver ends at 10° AOA.

Suggested Cooper-Harper Rating Performance Standards:
It is not recommended to use the Cooper-Harper Rating scale with this maneuver.

Comments and Notes:
1. Various AOAs/airspeeds should be included in this testing. The most critical cases for inertia coupling should be checked as well as any pinch-points in the nose-down pitching moment curve.

Potential Maneuver Variations

Variation A:
Setup:
Pilot can hold a constant longitudinal stick position during the initial roll instead of holding a constant AOA. This may be easier for the pilot to fly and give direct information on inertia coupling during the roll but may not result in as consistent condition for the push-over.

Variation B:
Setup:
It is desirable to reach maximum roll rate. The bank angle change before applying full forward stick can be adjusted to reach a higher roll rate. However, a relatively easily judged bank angle should be chosen to increase the repeatability of the maneuver.

STEM 6: Maximum Pitch Pull

The Maximum Pitch Pull maneuver is a very simple, open-loop maneuver that is operationally significant. It can be thought of as a maximum agility evaluation maneuver rather than a flying qualities task due to its open-loop nature. It is an important element of many other maneuvers, and it is a simple, repeatable method to test an aircraft's response to a maximum pitch input. The Maximum Pitch Pull maneuver can also be used to help define setups and limitations for other maneuvers (e.g. STEM 7 Nose-Up Pitch Angle Capture, and STEM 11 Sharkenhausen). Pitch response characteristics should be evaluated over a range of airspeed using this maneuver. Setups for low airspeed evaluations and medium to high airspeed evaluations have been defined. The low speed maneuver is useful for evaluating the pitch onset, maximum pitch rate, and maximum AOA achievable. It was found to generate primarily quantitative data; however, some pilot comments can also be gathered. During simulation it was used to evaluate variations in short period frequency, short period damping, and maximum AOA capability. Both AOA and pitch rate command systems have been tested with this maneuver.

A medium to high airspeed setup (Variation D) was also developed for the Maximum Pitch Pull maneuver. It requires the pilot to begin in a dive so that a larger angle change can be tested before terminating the maneuver due to excessive nose-high attitudes. The dive angle may be modified to assist in reaching a more stable setup. The medium to high speed version of this maneuver may have the potential for GLOC depending upon the configuration and flight condition. Variation D is useful for evaluating the pitch onset, maximum pitch rate, and maximum load factor achieved. It was found to generate primarily quantitative data; however, some pilot comments can also be obtained. During simulation it was used to evaluate variations in short period frequency, short period damping, and maximum load factor/AOA capability.

STEMS

STEM 6: Maximum Pitch Pull

Intent:
This maneuver represents a fundamental element of several maneuvers. It isolates an aggressive, open-loop longitudinal input over a range of airspeeds. It can be used to generate repeatable quantitative data and some qualitative data.

Applicable Classes and Flight Categories:
Class: I, IV **Category:** A **Phase:** CO

Performance Objective	Aircraft Attributes	Operational Applications
Generate maximum pitch rates and sustain a high pitch rate through a large pitch angle.	Pitch authority AOA authority Maneuverability Departure resistance	Initiate lead turn in vertical Pitch up for weapons shot Post-weapons off-target pull Generate overshoot (defensive) Collision avoidance Intimidate opponent

Setup:
Perform a wings level deceleration to target airspeed using a predetermined power setting. Stabilize flight path ($d\gamma/dt=0$), and set test power level. Level flight is desirable, but a steady dive may be necessary to test high AOA/low speed conditions. The aim condition tolerances are: airspeed ±5%, altitude ±2,000 feet, less than 5° of bank angle throughout maneuver. The best setup technique for each aircraft can be quickly determined with a simulator.

Maneuver:
Upon meeting all the initial condition criteria, aggressively input a full longitudinal stick pull (or placard limit) and other appropriate nose-up pitch controls. Use of lateral stick is allowed to maintain the bank tolerance of ±5°. Timing of the maneuver begins when longitudinal stick is employed and ends when the aircraft pitch rate has reduced to zero or the pitch angle has passed through the vertical.

Suggested Cooper-Harper Rating Performance Standards:
It is not recommended to use the Cooper-Harper rating scale with this maneuver because of its open-loop nature.

Comments and Notes:
1. Simulation should be conducted prior to flight test because the maneuver may result in unacceptable attitudes for flight test, i.e. nose-high, slow speed. The initial pitch attitude can be modified to improve the exit condition.

STEMS

Potential Maneuver Variations

Variation A:
Setup:
The following airspeeds can be tested to cover a range of aircraft characteristics:
Vmin, (Vmin+Vc)/2, and other low airspeeds as necessary.

Variation B:
Setup:
Various throttle settings should be tested especially for thrust vectored configurations and for aircraft with a significant vertical thrust line offset. It is recommended that idle, military, and maximum thrust settings be tested.

Variation C:
Maneuver:
It may be possible to continue this maneuver with a high AOA roll to gather additional lateral information from a single maneuver. The lateral data would probably not be as consistent as with a dedicated lateral maneuver.

Variation D:
Setup:
A slightly different setup was identified for medium to high speed conditions:
Starting from above test condition altitude and below test airspeed, set dive angle at -15° and set desired power level. The aim condition tolerances are: airspeed ±5%, altitude ±2,000 feet, pitch angle ±5°, less than 5° of bank angle throughout maneuver. The best set up technique for each aircraft can be quickly determined with a simulator.

The following airspeeds can be tested to cover a range of aircraft characteristics:
Vc, 0.9$Vmax_{(mil)}$, 1/2*(Vc+Vmax), and other medium and high airspeeds as necessary.

Note that depending upon the configuration, a potential for GLOC exists with this maneuver.

STEM 7: Nose-Up Pitch Angle Capture

The Nose-Up Pitch Angle Capture is a well-known maneuver that tends to be useful for flying qualities evaluations and is extremely operationally relevant. It is a simple maneuver that isolates a longitudinal capture task of a target aircraft. A pitch attitude capture can be accomplished using the Attitude Director Indicator (ADI) and/or Head-Up Display (HUD), but a target aircraft is highly recommended. The use of a target resulted in a more realistic task with higher pilot gains. The pilots had to alter their technique to compensate for the displays if a target aircraft was not being used for the capture task. The HUD displays moved too fast to allow a very aggressive capture.

The setup for this maneuver is identical to the Maximum Pitch Pull maneuver (STEM 6). Low airspeed and medium to high airspeed setups are defined just as they are for STEM 6. The pilot input should be aggressive for this task, however full stick is not necessarily required. Various pilot techniques should be examined. A variety of pitch attitudes can be examined, but care should be taken to avoid capturing the target near a performance limit. If the capture angle is chosen near the maximum obtained from STEM 6, then the flying qualities of the aircraft can be masked because the pitch rate may naturally slow down near that maximum pitch angle: therefore, any flying qualities deficiencies may be hidden. Overall, this maneuver generated good flying qualities data, pilot comments, and ratings, but it resulted in very few good measures of merit. As a result, it is recommended that this maneuver be used primarily for comments and ratings although some quantitative data may be collected. The low airspeed setup was used to successfully evaluate variations in short period frequency, short period damping, longitudinal stick sensitivity, and nonlinear longitudinal command gradients. Angle of attack, AOA rate, and pitch rate command systems were tested at the low airspeed flight condition. The medium to high airspeed setup was used to successfully evaluate variations in Control Anticipation Parameter (CAP), short period damping, and nonlinear longitudinal stick shaping. This STEM was also used successfully to evaluate the pitch characteristics of a transport aircraft (using a much smaller range of pitch attitudes). Extensive in-flight testing has also been conducted using similar pitch angle capture tasks.[14-15]

STEMS

STEM 7: Nose-Up Pitch Angle Capture

Intent:
This maneuver represents a fundamental element of several maneuvers. It isolates an aggressive longitudinal capture task at low airspeed. It is best suited to generate qualitative data but also provides some quantitative data.

Applicable Classes and Flight Categories:
Class: IV **Category:** A **Phase:** CO, WD

Performance Objective	Aircraft Attributes	Operational Applications
Pitch and capture a target in minimum time.	Longitudinal flying qualities Pitch performance PIO tendencies Maneuverability	Launch missile at bandit Intimidate opponent Guns attack

Target Setup and Maneuver:
Fly straight and level at a constant speed with the initial downrange and altitude set to establish the desired capture angle. Fly slightly slower than the test aircraft initial speed so that the formation can be more easily maintained as the test aircraft performs captures. Target needs to be distant to maintain the desired angle during the maneuver.

Setup:
Perform a wings level deceleration to target airspeed using a predetermined power setting. Stabilize flight path ($d\gamma/dt=0$), and set test power level. The aim condition tolerances are: airspeed ±5%, altitude ±2,000 feet, less than 5° of bank angle throughout maneuver. The best setup technique for each aircraft can be quickly determined with a simulator.

Maneuver:
Upon completing the setup, the pilot uses longitudinal stick to capture the target pitch angle as quickly as possible and maintain attitude within an 80 mil horizontal band (or reticle) (approximately ±2°) for 1 second. The pilot should experiment to find the best technique to minimize capture time. Use of lateral stick is allowed to maintain the bank tolerance of ±5°. Timing of the maneuver begins when longitudinal stick is employed and ends when the aircraft first meets the capture criteria successfully.

Suggested Cooper-Harper Rating Performance Standards:

Desired: Aggressively acquire aim point within the 80 mil error bars with no more than 1 longitudinal overshoot and within desired time.

Adequate: Aggressively acquire aim point within the 80 mil error bars with no more than 2 longitudinal overshoots and within adequate time.

Comments and Notes:

1. A pitch attitude can be chosen so that the capture occurs during a transient maneuver (maximum pitch rate is not attained before the pilot begins the capture). A larger pitch attitude can also be chosen so that the maximum pitch rate is attained before the pilot begins to capture the desired pitch attitude. STEM 6 can be flown prior to this maneuver to help select appropriate pitch attitudes.

2. A target aircraft is desirable if available, but the task can be performed with head-down displays or a HUD. Modified HUD displays might allow more aggressive maneuvers because a standard pitch ladder may move too fast to enable aggressive accurate captures.

3. Do not conduct captures near the maximum pitch angle achievable (determined from STEM 6). A capture at or near this maximum attainable pitch angle can mask flying qualities deficiencies because the aircraft is hitting a performance limitation.

Potential Maneuver Variations

Variation A:
Setup:
The following airspeeds can be tested to cover a range of aircraft characteristics:
Vmin, (Vmin+Vc)/2, and other low airspeeds as necessary.

Variation B:
Setup:
Various throttle settings should be tested especially for thrust vectored configurations and for aircraft with a significant vertical thrust line offset. It is recommended that idle, military, and maximum thrust settings be tested.

Variation C:
Setup:
A slightly different setup was identified for medium to high speed conditions:
Starting from above test condition altitude and below test airspeed, set dive angle at -15° and set desired power level. The aim condition tolerances are: airspeed ±5%, altitude ±2,000 feet, pitch angle ±5°, less than 5° of bank angle throughout maneuver. The best set up technique for each aircraft can be quickly determined with a simulator.

The following airspeeds can be tested to cover a range of aircraft characteristics:
Vc, $0.9Vmax_{(mil)}$, (Vc+Vmax)/2, and other medium and high airspeeds as necessary.

STEM 8: Crossing Target Acquisition and Tracking

The Crossing Target Acquisition and Tracking maneuver involves a multiple-axis acquisition and tracking of an air-to-air target. It can be used to evaluate the overall harmony of a configuration, including the blending between acquisition and tracking. The maneuver begins with a primarily pitch acquisition which is immediately followed by a pitch/roll/yaw tracking task that occurs while the pilot is unloading the aircraft and reversing to follow the target. The task then transitions back to a pure pitch tracking task at the end. It is useful to evaluate this maneuver with various pilot techniques (as described in Variation C). Pilot comments are the primary source of data from this maneuver because it is too free-form to calculate and correlate measures of merit effectively. Pilot ratings were also taken, however the pilot comments tended to be more valuable due to the multi-axis, multi-task nature of the maneuver. It was effectively used to evaluate variations in short period frequency, roll rate command sensitivity, and roll mode time constant. Finally, it was flown with both AOA and AOA rate command systems.

STEMS

STEM 8: Crossing Target Acquisition and Tracking

Intent:
This maneuver allows the acquisition and tracking capabilities of an aircraft to be exercised through a multiple-axis acquisition of a target aircraft. The maneuver will require the test aircraft to generate and stop a pitch rate to capture the target as well as perform a multiple axis tracking task on a crossing target. The ability to pull to moderately high AOA, stop the pitch rate, laterally track a target while unloading in AOA, and then transition to longitudinal tracking are tested.

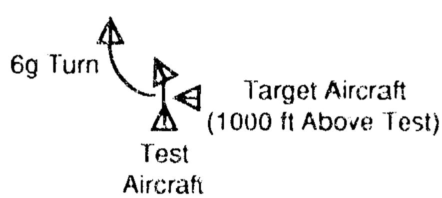
Applicable Classes and Flight Categories:
Class: IV **Category:** A **Phase:** CO

Performance Objective	Aircraft Attributes	Operational Applications
Conduct acquisition and tracking of a close range target aircraft	Longitudinal flying qualities Lateral flying qualities Directional flying qualities Multi-axis flying qualities Roll performance Pitch performance Turn performance PIO tendencies	Launch weapon Lead turn

Target Setup and Maneuver:
Target begins at Vc with a 90° crossing angle, 1000 ft above the test aircraft. After passing above the test vehicle, the target begins a 5-6g level turn into the test vehicle. The target maintains 5-6g in level flight until the end of the maneuver.

Setup:
Begin in 1-g level flight at a trimmed power setting at Vmin.

Maneuver:
When the target passes overhead, turn up and into the target. Aggressively acquire and track the target. The target should be held in a 30 mil reticle for 2 seconds before the capture is considered complete.



Suggested Cooper-Harper Rating Performance Standards:

Desired: Aggressively acquire aim point within the 30 mil reticle with no more than 1 overshoot and within a desired time to accomplish the task. Maintain the target within the 30 mil reticle at least 50% of the time during tracking.

Adequate: Aggressively acquire aim point within the 30 mil reticle with no more than 2 overshoots and within an adequate time to accomplish the task. Maintain the target within the 30 mil reticle for at least 10% of the time during tracking.

Comments and Notes:
1. The initial altitude difference and g profile of the target can be varied to change the difficulty of the task.

STEMS

Potential Maneuver Variations

Variation A:
Setup:
The following airspeeds can be tested to cover a range of aircraft characteristics:
Vmin, (Vmin+Vc)/2, Vc

Variation B
Maneuver:
The maneuver may be completed 3 ways. First, the pilot can drive the pipper to the target as aggressively as possible and then track the target through the reversal. Second, the pilot can anticipate the required reversal and lead the turn. Or finally, the maneuver may be terminated after the target is initially captured, i.e. only perform the gross acquisition of the target with no tracking or reversal required.

STEM 9: Pitch Rate Reserve

The pitch rate reserve maneuver is a single-axis, open loop maneuver designed to test nose-pointing capability from a turning condition. It is primarily useful to look at pitch rate onset, maximum attainable pitch rate, and maximum AOA. This maneuver was defined from the "Angular Reserve" maneuver tested in References 14 and 15. It is similar to the Maximum Pitch Pull maneuver (STEM 6), except that it is conducted from a loaded condition in a level turn. It can also be considered as an open-loop version of the High AOA Longitudinal Gross Acquisition maneuver (STEM 10) and can be used to help define the constraints for STEM 10. The Pitch Rate Reserve maneuver can be initiated from the AOA for maximum lift or any other pertinent AOA. It proved useful for generating quantitative data and some pilot comments were received, but it cannot be used for flying qualities development work because it is not a closed-loop task. It was used successfully to determine variations in short period frequency, short period damping, and maximum attainable angle of attack.

STEMS

STEM 9: Pitch Rate Reserve

Intent:
This maneuver is intended to demonstrate the reserve pitch authority available from a loaded condition. It primarily generates quantitative data but also provides some qualitative data.

Applicable Classes and Flight Categories:
Class: IV **Category:** A **Phase:** CO

Performance Objective	Aircraft Attributes	Operational Applications
Rapidly pitch nose toward a target from a high AOA condition.	Pitch authority	Pull to force overshoot
	AOA authority	Missile jink
	Pitch performance	SAM break
	Maneuverability	Nose intimidation
	Departure resistance	Quick lock for earliest shot
	Turn performance	

Setup:
The pilot establishes a level turn at the desired AOA and airspeed and selects the desired test power setting.

Maneuver:
Upon completing the setup, the pilot applies a pure longitudinal, full aft stick snatch. The pilot holds full aft stick until the nose rate drops below the initial turn rate.

Suggested Cooper-Harper Rating Performance Standards:
It is not recommended to use the Cooper-Harper rating scale with this maneuver because it is open-loop.

Comments and Notes:
1. The best setup technique may depend upon configuration. The technique used during initial maneuver development consisted of maintaining maximum power setting in a constant AOA turn until airspeed bled down to the test airspeed. Other setup techniques might include a constant airspeed turn with increasi.ıg AOA, or a constant g turn.

2. A vertical velocity indicator would be helpful to establish a level turn at high AOA. Without it, altitude control is difficult since the flight path marker (velocity vector) is typically outside the HUD field of view.

Potential Maneuver Variations

Variation A:
Setup:
The maneuver initiation can begin at any tactically realistic condition such as sustained turn rate, buffet onset, or some other desired test AOA and airspeed.

STEM 10: High AOA Longitudinal Gross Acquisition

The High AOA Longitudinal Gross Acquisition maneuver can be used for the evaluation of longitudinal flying qualities at high AOA. It was developed and tested under MDA[7-9] and NASA sponsored[10-11] research to develop flying qualities criteria at several angles of attack. It is included as one of the initial STEMS maneuvers because of its applicability to high AOA and the fact that it is a relatively newly developed maneuver. Detailed maneuver descriptions can be found in References 8, 10, and 11 for each AOA tested. A general description, that can be modified to a wide range of AOA, is shown on the maneuver description sheet. Specific test conditions for 30°, 45°, and 60° AOA are shown in the Variations section. Pilot comments and ratings are the primary data generated from this maneuver. In addition, some measure of merit data has been shown to correlate with the comments and flying qualities criteria boundaries from this maneuver. The High AOA Longitudinal Gross Acquisition maneuver has been used to evaluate variations in short period frequency, short period damping, and thrust vectoring nozzle rate limits. This task has been used to evaluate aircraft models with AOA, AOA rate, pitch rate, and blended longitudinal command systems. It was successfully tested in flight during an Air Force Test Pilot School class project;[12] however, this testing was at low to moderate AOA. It is also planned to be used to evaluate the HARV at high AOA.

STEMS

STEM 10: High AOA Longitudinal Gross Acquisition

Intent:
This maneuver is intended to isolate the flying qualities characteristics of an aircraft during a high AOA longitudinal capture task. The data generated is primarily qualitative in nature but some quantitative data may also be obtained.

Applicable Classes and Flight Categories:
Class: IV **Category:** A **Phase:** CO

Performance Objective	Aircraft Attributes	Operational Applications
Conduct a high AOA gross acquisition of a target aircraft.	Longitudinal flying qualities Pitch performance PIO tendencies	Weapons acquisition Nose intimidation

Target Setup and Maneuver:
The target sets the desired power setting. The target then rolls and pulls into a constant AOA descending turn. Bank angle should be adjusted to maintain a predetermined airspeed.

Setup:
The evaluation aircraft begins in 1-g level flight approximately 3000 ft directly behind the target aircraft. The task is initiated above the desired data-taking altitude at a predetermined airspeed.

Maneuver:
Allow target to reach a predetermined angle off nose. Roll to get into the target's maneuver plane and set throttles at test setting. Hesitate until lag position behind target will result in the test AOA during the capture. Aggressively acquire the target within an 80 mil horizontal band (or reticle). After the capture is complete, unload, allow the target to drift to an offset, and perform another capture. Multiple acquisitions can be performed before breaking off the maneuver. Simulator practice is highly desirable to establish the best target profile and a consistent set up for the acquisitions.

Suggested Cooper-Harper Rating Performance Standards:

Desired: Aggressively acquire aim point within 80 mils with no more than 1 longitudinal overshoot and within a desired time to accomplish the task.

Adequate: Aggressively acquire aim point within 80 mils with no more than 2 longitudinal overshoots and within an adequate time to accomplish the task.

Comments and Notes:
1. This maneuver was developed and tested under another effort. The general maneuver description is given here. Specific maneuvers were developed for 30°, 45°, and 60° AOA. The 30° and 45° AOA tasks are described in detail in NASA CR-4435, "Flying Qualities Criteria Development Through Manned Simulation for 45° Angle of Attack - Final Report" and the 60° AOA task is described in "Flying Qualities Criteria Development for 60° Angle of Attack" (NASA CR to be published in 1993).

2. The desired and adequate time referenced in the Cooper-Harper performance standards can be left vague to try to identify an operationally meaningful time from the piloted data. The performance criteria times can then be strictly defined to reduce variability. The research in "Flying Qualities Criteria Development for 60° Angle of Attack" indicates that 5.5 sec correlated with the pilots perception of desired time to perform this task at 60° AOA.

STEMS

STEM 10: High AOA Longitudinal Gross Acquisition

Potential Maneuver Variations

Variation A:
Target Setup and Maneuver:
The target aircraft can fly a steeper descent to test higher airspeed captures.

Variation B:
Target Setup and Maneuver:
The pilot can test a range of lag offsets to the target to exercise a range of capture AOAs. Pilot comments should be studied and if a problem is observed around a certain AOA range, more exhaustive testing can be performed exclusively at that AOA.

Variation C: (Specifics required for 30° AOA testing, F/A-18 target, HARV evaluation)
Target Setup and Maneuver:
Target starts at M=0.6, H=25000 ft. Target rolls and pulls to establish a descending turn at 20° AOA and tries to maintain 200 kt.

Variation D: (Specifics required for 45° and 60° AOA testing, F/A-18 target, HARV evaluation)
Target Setup and Maneuver:
Target starts at M=0.5, H=25000 ft. Target rolls and pulls to establish a descending turn at 25° AOA and tries to maintain 170-180 kt.

STEM 11: Sharkenhausen

The Sharkenhausen maneuver is an excellent tactical representation and a good test of control harmony. It requires a rapid, accurate, combined axis capture of an oncoming target. This maneuver is primarily recommended for simulation evaluation. It should be investigated in flight, but the setup geometry may be very difficult to establish in flight and is critical to the outcome of the maneuver. The intent of this maneuver is to perform a rapid acquisition of the target, rather than allowing the task to proceed into a tail-chase situation. It can be used to compare different variations of a configuration at a set initial condition. It can also be used to determine the minimum initial downrange separation at which the maneuver could be accomplished with a certain configuration. This minimum downrange separation can then be used to demonstrate capability differences. Pilot ratings were taken during the simulation, even though this is a combined axis task. It was found that the pilot comments were much more important than the ratings. Some measures of merit were successfully used to evaluate design parameter variations, but others were dominated by pilot variability. The measures of merit were highly sensitive to variations on initial range. The Sharkenhausen maneuver was used to evaluate variations in longitudinal dynamics (combinations of short period frequency and short period damping), lateral dynamics (combinations of maximum roll rate and roll mode time constant), and maximum attainable AOA. It has been used to evaluate AOA, AOA rate, and pitch rate command systems in the longitudinal axis.

STEMS

STEM 11: Sharkenhausen

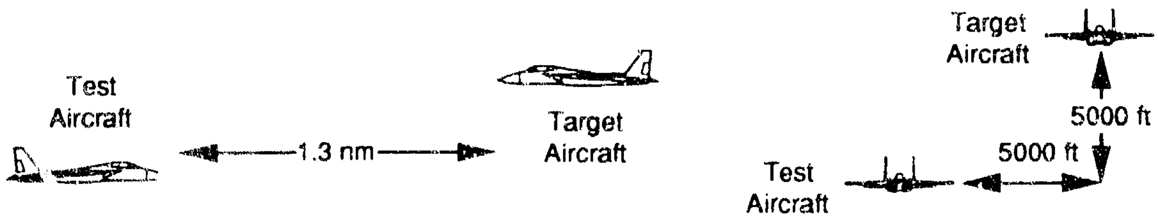
Intent:
This maneuver allows the acquisition capabilities of an aircraft to be exercised through a multiple-axis acquisition of a target aircraft. The ability to pull to moderately high AOA and maintain good lateral control on a crossing target is emphasized.

Applicable Classes and Flight Categories:
Class: IV **Category:** A **Phase:** CO

Performance Objective	**Aircraft Attributes**	**Operational Applications**
Conduct a gross acquisition of an approaching target aircraft	Longitudinal flying qualities	Launch missile
	Lateral flying qualities	Late radar/visual pickup
	Directional flying qualities	Velocity vector management
	Multi-axis flying qualities	
	PIO tendencies	
	Roll performance	
	Pitch performance	
	AOA authority	
	Maneuverability	
	Turn performance	

Target Setup and Maneuver:
Target begins co-speed with the test aircraft and with a 180° heading difference. Target aircraft begins 5000 ft abreast and 5000 ft higher than the test aircraft. During the maneuver, the target aircraft maintains straight and level flight at constant airspeed.

Setup:
Begin in 1-g level flight at a trimmed power setting.



Maneuver:
When the target reaches a position 1.3 nm downrange, aggressively acquire and track the target. The target should be captured in an 80 mil reticle for 2 seconds.

Suggested Cooper-Harper Rating Performance Standards:

Desired: Aggressively acquire aim point within the 30 mil reticle with no more than 1 overshoot and within a desired time to accomplish the task.

Adequate: Aggressively acquire aim point within the 80 mil reticle with no more than 2 overshoots and within an adequate time to accomplish the task.

Comments and Notes:

1. The initial geometry was varied during simulation until all the test configurations could acquire the target without requiring a tail chase. This range may need to be altered for different configurations. One variation on this maneuver is to vary the initial downrange to determine at what minimum range an aircraft performance limitation is reached.

2. This maneuver is probably best performed in a simulator due to the sensitivity upon initial geometry.

Potential Maneuver Variations

Variation A:
Maneuver:
Testing can be conducted at various initial downranges to determine the minimum range that still allows a capture of the target before a tail chase is required. The character of the task is completely different if a tail chase is allowed; therefore, this data should not be used for comparison other than the fact that the capture was not obtainable before a tail chase occurred.

Variation B:
Setup:
The following airspeeds can be tested to cover a wide range of aircraft characteristics:
Vmin, Vc, (Vc+Vmax)/2

STEM 12: High AOA Roll Reversal

The High AOA Roll Reversal maneuver is designed to demonstrate high AOA/low speed roll capability and coordination. The intent is to evaluate the roll performance of an aircraft at a relatively constant AOA. It requires the use of full roll controls to start the roll and full opposite roll controls to reverse the roll. As a result, it can be used to evaluate the maximum attainable roll rate, roll coordination, and surface rate and position limiting during the reversal. It was developed from the suggestion of a "High AOA Roll Reversal" maneuver in Reference 14. It is recommended that the Reference 14 setup be used at lower AOA and this maneuver be used for higher AOA. The setup for this maneuver is designed to get the velocity vector in a vertical orientation for more stabilized conditions. A variety of angles of attack can be tested, but there is very little control over the test airspeed. The amount of heading change used during the maneuver can be altered to suit the specific test objectives and the aircraft being tested. Smaller heading changes will concentrate the evaluation on the initial roll response, and larger heading changes will be useful to evaluate maximum roll rate and coordination attributes. This maneuver is a demonstration of open-loop dynamics and is not intended for the development of closed-loop flying qualities. It results in primarily quantitative data being generated. It was successfully used to evaluate variations in maximum attainable roll rate, roll mode time constant, and roll acceleration limits.

SEMS

STEM 12: Loaded Roll Reversal

Intent:
This maneuver allows the investigation of high AOA roll performance in a relatively stabilized flight condition. Roll onset as well as the aircraft response to a large cross-check input can be evaluated. Quantitative data is the primary output of this maneuver.

Applicable Classes and Flight Categories:
Class: IV **Category:** A **Phase:** CO

Performance Objective	Aircraft Attributes	Operational Applications
Roll quickly and change direction of roll rapidly while at high AOA	Roll performance Roll coordination Roll authority Departure resistance	High AOA roll capability (lift vector control at high AOA)

Setup:
The entry to this maneuver is basically a split-S. Starting above test airspeed and above test altitude, roll inverted and pull to target AOA, setting thrust as required. Hold AOA as pitch angle pulls through to (-90° + test AOA) (i.e. where velocity vector is vertical).

Maneuver:
As soon as the above condition is reached, apply maximum roll control. Hold AOA while rolling (appears as yaw). Choose an outside reference point approximately 180° past the heading at which the roll was initiated. Upon reaching the desired heading, apply full opposite roll control and hold until passing initial heading.

Suggested Cooper-Harper Rating Performance Standards:
It is not recommended to use the Cooper-Harper Rating scale with this maneuver because it is open-loop.

Comments and Notes:

1. Various angles of attack can be tested with this maneuver. However, this maneuver is intended to be used at post-stall angles of attack. If used at lower angles of attack or with configurations with very low roll rates, the velocity vector will not remain as close to vertical.

2. The wind axis bank angle cannot be used as a measure of merit during data processing because of the singularity present when the velocity vector is vertical. It is recommended that the integral of wind axis roll rate be used instead.

Potential Maneuver Variations

Variation A:
Maneuver:
Various heading changes can be used for this task. Larger heading changes can be used to ensure that the maximum roll rate is achieved and to better examine possible roll coordination problems. Smaller heading changes may be more appropriate for configurations with low maximum roll rates.

STEM 13: High AOA Roll and Capture

The High AOA Roll and Capture maneuver is designed to isolate high AOA roll capability and controllability. It has a similar intent as the High AOA Lateral Gross Acquisition maneuver (STEM 10), but this maneuver allows a larger angle change and higher maximum rates to be developed. However, it does not require as demanding a capture because of the lack of a target aircraft. Therefore fewer flying qualities deficiencies may be identified. This maneuver was based on a modification to the "High AOA Roll" maneuver proposed in Reference 14. The High AOA Roll and Capture maneuver is intended primarily for post-stall angles of attack and the Reference 14 maneuver is recommended for lower AOA. The setup is identical to the High AOA Roll Reversal maneuver (STEM 12), and it is designed to get the velocity vector straight down to achieve a more stable condition. This maneuver requires a clearly distinguished landmark to initiate the maneuver and complete the capture. It was preferred to use a landmark for a capture instead of a heading on the HUD to be more representative of an air-to-air task and minimize problems with the display update rates and readability. This maneuver does not work well for configurations with very slow roll rate capability because the velocity vector does not stay vertical after a period of time. The High AOA Roll and Capture maneuver was used to evaluate variations in maximum attainable roll rate and roll mode time constant. It was flown with aircraft models that used AOA and rate command systems in the longitudinal axis. The rate command system was more difficult to maintain a desired AOA throughout the maneuver. However, it was easy for the pilot to monitor and control pitch attitude during roll, which then resulted in a roughly constant AOA.

STEMS

STEM 13: High AOA Roll and Capture

Intent:
This maneuver is intended to isolate the flying qualities characteristics of an aircraft during a high AOA lateral capture task. The data is primarily qualitative in nature but some quantitative data may also be obtained.

Applicable Classes and Flight Categories:
Class: IV **Category:** A **Phase:** CO

Performance Objective	Aircraft Attributes	Operational Applications
Conduct a high AOA lateral acquisition by capturing a heading.	Lateral flying qualities Roll performance Roll coordination	Shift targets Turn reversal Weapons acquisition Nose intimidation

Setup:
The entry to this maneuver is essentially a split-S. Starting above test airspeed and above test altitude, roll inverted and pull to target AOA, setting thrust as required. Hold AOA as pitch angle pulls through to (-90° + test AOA) (i.e. where velocity vector is vertical).

Maneuver:
As soon as the above condition is reached, aggressively initiate full roll control. Maintain target AOA during entire maneuver including the capture. Continue the turn through approximately 360° to capture the initial heading. Lead the roll out as necessary to capture the initial heading.

Suggested Cooper-Harper Rating Performance Standards:

Desired: Aggressively roll and acquire heading change within 80 mils with no more than one overshoot, and within a desired time to perform task.

Adequate: Aggressively roll and acquire heading change within 80 mils with no more than two overshoots, and within an adequate time to perform task.

Comments and Notes:

1. Various angles of attack can be tested with this maneuver. However, this maneuver is intended to be used at post-stall angles of attack.

2. The maneuver is best set up 180° out from a major landmark (runway, mountain, section line). This provides a visible initial heading reference and subsequent capture landmark.

Potential Maneuver Variations

Variation A:
Maneuver:
Various heading changes can be used for this task. Larger heading changes can be used to ensure that the maximum roll rate is achieved and to better examine possible roll coordination problems.

Variation B:
Maneuver:
If the longitudinal control system does not command AOA, it may be easier for the pilot to maintain a constant pitch attitude during the roll rather than AOA. This results in a relatively constant AOA roll for this maneuver. This technique also allows the pilot to concentrate more on the lateral axis.

STEM 14: Minimum Speed Full Stick Loop

The Minimum Speed Full Stick Loop maneuver is designed to determine the minimum speed at which the pilot can perform a full stick input and the aircraft will continue through a loop. It is not meant to be an energy-maneuverability loop (although that is also valuable to test). It was developed as a safe method to determine the airspeed band in which full aft stick cannot be used to perform a loop in an operational environment. This maneuver may also be useable as a possible AOA envelope expansion technique. During the Minimum Speed Full Stick Loop, the pilot attempts a loop from the low speed and high speed sides to define the undesirable airspeed band. This maneuver was successfully used to demonstrate differences due to the addition of thrust vectoring.

STEMS

STEM 14: Minimum Speed Full Stick Loop

Intent:
This maneuver is intended to define the minimum controllable airspeed that is required to maneuver through 90° vertical and continue the maneuver to an upright straight and level attitude. Information on pitch authority at low speeds in the vertical as well as roll stability information may also be obtained.

Applicable Classes and Flight Categories:
Class: IV **Category:** A **Phase:** CO

Performance Objective	Aircraft Attributes	Operational Applications
Maintain pitch control and authority through a full loop.	Pitch authority	Minimum "over-the-top" speed
	AOA authority	Vertical reposition
	Maneuverability	Defensive counter/Vertical attack
	Roll performance	
	Turn performance	
	Axial performance	
	Departure resistance	

Setup (Slow Speed):
Start maneuver below required speed to complete a loop.

Maneuver (Slow Speed):
Pull into the vertical using full aft stick and note maximum achievable pitch attitude and pitch rate. Repeat maneuver by increasing entry airspeed in 10 knot increments until 80° pitch attitude is reached. Do not exceed 80° pitch attitude. i.e. unload aircraft prior to exceeding 80° pitch attitude. Note the pitch rate as attitude approaches 80°. Note the minimum speed to reach 80° pitch attitude.

Setup (High Speed):
Start maneuver at 100 knots above the minimum required speed to reach 80° pitch attitude.

Maneuver (High Speed).
Pull into the vertical using full aft stick (or maximum allowable load factor) and continue through 90° vertical. After passing through the vertical continue pull until reaching an upright, wings level attitude (0° pitch is reached) or maximum nose up pitch attitude is reached whichever is less. Decrease the entry airspeed in 10 knot increments and repeat maneuver until the nose rate over the top slows to 5 deg/sec or less. Note the minimum entry airspeed to complete the over-the-top maneuver with 5 deg/sec rate.

Suggested Cooper-Harper Rating Performance Standards:
It is not recommended to use the Cooper-Harper Rating scale with this maneuver.

Comments and Notes:
1. The two airspeeds determined above define an airspeed range in which the pilot will not be able to complete an over-the-top maneuver or will have marginal authority and control. The build-up provides a test of controllability and control power across the AOA range

STEM 15: Minimum Time 180° Heading Change

The Minimum Time 180° Heading Change maneuver is a freestyle maneuver that is intended to demonstrate the ability to change heading by 180°. It is included so that several tactics can be compared and an aircraft's ability to perform these maneuvers can be contrasted. It is hoped that this maneuver will allow any unique maneuver capability to be compared to more conventional tactics. Ideally, the aircraft can perform this maneuver quickly using many different techniques thereby providing the pilot with more options and allowing him to be more unpredictable in combat. The maneuver description specifies the start and end conditions rather than the technique required to transition between them. For consistency, the end condition requires a heading angle change of 180° and requires that the nose be returned to the horizon. The data generated from this maneuver is very qualitative in nature because it tends to be more of a demonstration maneuver. Pilot comments, the time to perform each technique, and the aircraft time history data are the most valuable pieces of information resulting from this maneuver. A variation in capability was demonstrated during simulation by testing the addition of thrust vectoring.

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STEM 15: Minimum Time 180° Heading Change

Intent:
This maneuver is intended to demonstrate the possible options a pilot has available to change the aircraft heading by 180°. It should include testing of conventional methods such as level turns, the split-S, and slices as well as techniques such as a J-Turn. This maneuver is a freestyle maneuver and results in qualitative data.

Applicable Classes and Flight Categories:
Class: IV **Category:** A **Phase:** CO

Performance Objective	Aircraft Attributes	Operational Applications
Change heading by 180° in minimum time.	Maneuverability Pitch performance Roll performance Axial performance	All Airspeeds: Target switch Attack abort - bugout Between Vc and Vmax: Missile defense (drag maneuver) Initial WVR turn

Setup:
Begin in 1g level flight at target airspeed.

Maneuver:
Experiment to determine best technique for turning through 180° heading change in minimum time. The maneuver is complete when the aircraft comes through 180° heading change and the nose is level with the horizon. No capture is required.

Suggested Cooper-Harper Rating Performance Standards:
It is not recommended to use the Cooper-Harper rating scale with this maneuver.

Comments and Notes:
1. It is desirable to look at the variation in times with technique (i.e. plane of maneuver, etc.). Less variation is better since this offers the pilot the most possible options and he is therefore less predictable to the adversary.

Potential Maneuver Variations

Variation A:
Maneuver:
The following airspeeds can be tested to cover a wide range of aircraft characteristics:
(Vmin+Vc)/2, (Vc+Vmax)/2, or others as desired

STEM 16: 1-g Stabilized Pushover

The 1-g Stabilized Pushover maneuver can be used to isolate the nose down control power available at a high AOA condition. It has excellent repeatability because of its stabilized entry condition and simple, open-loop pilot input. This maneuver was developed and tested under NASA/USN research.[16] It is included as one of the initial STEMS maneuvers because of its applicability to high AOA and the fact that it is a relatively newly developed maneuver. This maneuver generates primarily quantitative data and some pilot comments. Ratings have been taken using the NASA/USN Pitch Recovery Rating (PRR) scale.[16,17] The test matrix for this maneuver should be concentrated around any pitching moment pinch points and include various angles of attack and center of gravity locations. This maneuver has been used successfully to evaluate variations in center of gravity location, and control power variations in simulation. It has been successfully tested in flight using the HARV and production F-18 aircraft. Additional in-flight validation of this maneuver was conducted as a part of an Air Force Test Pilot School project;[13] however, this testing was at low to moderate AOA

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STEM 16: 1g Stabilized Pushover

Intent:
This maneuver allows a stabilized evaluation of the nose-down pitch authority at high AOA. This maneuver generates very consistent quantitative data.

Applicable Classes and Flight Categories:
Class: IV **Category:** A **Phase:** CO

Performance Objective	Aircraft Attributes	Operational Applications
Unload rapidly from a low speed/high AOA condition.	Pitch performance Pitch control margin Pitch authority	Unload to accelerate or return to conventional envelope Collision avoidance

Setup:
From level flight, smoothly apply aft stick and capture a predetermined pitch attitude. Achieve a stabilized AOA and flight path angle at a fixed power setting. (It is desired to have zero pitch rate and stabilized flight at pushover.)

Maneuver:
Aggressively apply full forward stick until below 10° AOA.

Suggested Cooper-Harper Rating Performance Standards:
It is not recommended to use the Cooper-Harper rating scale with this maneuver because it is open-loop. However, a special Pitch Recovery Rating scale was developed by NASA/USN for use with this maneuver.

Comments and Notes

1. Testing should be conducted at AOA for minimum nose down pitching moment (pinch point) or any other AOA at which nose down control is questionable. Also should test from tactically relevant AOAs such as the AOA for Clmax and AOAmax.

2. This maneuver was developed under another effort. The general maneuver description is given here. The original study is detailed in NASA Conference Publication 3149 "High Angle of Attack Nose Down Pitch Control Requirements for Relaxed Static Stability Combat Aircraft".

Potential Maneuver Variations

Variation A:
Setup:
Various throttle settings should be tested especially for thrust vectored configurations and for aircraft with a significant vertical thrust line offset. It is recommended that idle, military, and maximum thrust settings be tested if a stabilized attitude can be maintained.

Variation B:
Maneuver:
A target capture task could be used to finish the maneuver. This would verify that the pitch rate built up throughout the maneuver could be controllably stopped. It would also allow a low speed longitudinal flying qualities evaluation. The Cooper Harper rating scale would be appropriate for this variation.

Variation C:
Setup and Maneuver:
A similar but inverted maneuver could be used to test the ability to unload from a negative g or AOA condition.

STEM 17: J-Turn

The J-turn is designed to demonstrate high AOA pitch and roll authority and evaluate simultaneous demands on pitch and roll power. It can be used to evaluate roll capability over a wide range of AOA. It was developed to emulate the capabilities needed to perform high AOA tactics[18] that were identified in the Multi-System Integrated Controls (MuSIC) simulation studies.[19] The J-Turn does require a general heading capture, but it is not a precise capture, and therefore it is not intended as a Cooper-Harper Rating task. Instead, this maneuver is primarily used to gather comments and observe the general capabilities of a configuration. A sluggish roll will stand out because the pilot will be unable to complete the maneuver properly. Different combinations of pitch and roll authority will result in much different trajectories. For example, this maneuver will essentially become a Split-S for configurations with low AOA authority and high roll authority. Some useful measures of merit can be generated from this maneuver, but it is primarily designed to be a demonstration maneuver. It was used to test variations in short period frequency, maximum roll rate, longitudinal command type, and thrust vectoring. It was used to test AOA, AOA rate, and blended longitudinal rate command systems.

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STEM 17: J-Turn

Intent:
This maneuver requires the simultaneous use of high AOA pitch and roll authority. It serves as a good demonstration maneuver for high AOA maneuverability.

Applicable Classes and Flight Categories:
Class: IV **Category:** A **Phase:** CO

Performance Objective	Aircraft Attributes	Operational Applications
Rapidly roll over a wide AOA range.	Roll performance Roll authority Pitch performance Pitch authority	Minimum time nose high reversal

Setup:
Begin in straight and level flight over a straight road or landmark and aligned with

Maneuver:
Apply a simultaneous rapid full aft, full lateral control (stick and/or rudder pedal) input. Remove the lateral input once the heading has changed 180° or the aircraft reaches a wings-level inverted position. Continue maintaining full aft stick. The objective is to finish the maneuver nose-low, 180° out from the initial heading and track the nose back up to the horizon.

Suggested Cooper-Harper Rating Performance Standards:
It is not recommended to use the Cooper-Harper rating scale with this maneuver.

Comments and Notes:
1. The maneuver should be performed until the nose passes through 0° pitch attitude, but the data can be compared at any pitch attitude prior to that. For example, it may be desirable to terminate the data analysis at -90° or -45° pitch attitude to better isolate the initial portion of the maneuver.

Potential Maneuver Variations

Variation A: (Yet Untried in Simulation)
Target Setup and Maneuver:
A target begins in straight and level flight at approximately 200 kt with a 180° heading difference from the test aircraft. The target begins 3000 ft above the test aircraft and initiates a split-S to a loop when directly over the test aircraft.
Setup:
The test aircraft begins in straight and level flight at Vc.
Maneuver:
After the target passes overhead and begins its split-S, the test aircraft maneuvers as necessary to acquire and track the target.

Note: This variation may be enough different from STEM 17 to warrant a new STEM number, if it proves successful

STEM 18: Tanker Boom Tracking

The Tanker Boom Tracking maneuver can be used as a high gain tracking task to uncover potential PIO problems. It is used as part of Air Force Test Pilot School training and has been used to evaluate the C-17. During the task, the pilot maintains a position slightly behind the boom and evaluates the ability to precisely control the aircraft relative to the refueling probe. It was flown during simulation by tracking a fixed boom, but it can also be conducted with the boom operator moving the probe. If a stationary probe is used, it is valuable to evaluate the ability to reposition between the probe wingtips and the tip of the probe. This helps excite any possible controllability problems. The primary data consists of pilot comments, ratings, and other qualitative information. This maneuver was flown in the simulator using both fighter and transport aircraft. It is believed to be more difficult to fly in the fixed-base simulator than it is in flight. It appeared that PIO tendencies were exaggerated and it was difficult to control the range to probe. These were attributed to the reduced pilot cues as compared to flight. It is still believed to be a valuable task; however, fixed-base simulation may result in an overly pessimistic evaluation. Variations in short period frequency, short period damping, and roll mode time constant were evaluated in the fixed-base simulation. This maneuver has already been conducted in flight, but it would be also interesting to test in a motion-base simulator.

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STEM 18: Tanker Boom Tracking

Intent:
This maneuver is intended to evaluate high gain flying qualities. It will highlight high gain/high sensitivity flight control system deficiencies and possibly uncover low phase and gain margins. This maneuver provides primarily qualitative data in the form of pilot comments although Cooper-Harper Ratings, PIO ratings, and frequency response analysis data may be appropriate for certain configurations.

Applicable Classes and Flight Categories:
Class: all **Category:** A **Phase:** RR

Performance Objective	Aircraft Attributes	Operational Applications
Precisely track and maintain range to the tanker boom. Precise attitude, altitude, and airspeed control.	Longitudinal flying qualities Lateral flying qualities Directional flying qualities Axial flying qualities Multi-axis flying qualities PIO tendencies	Aerial refueling Formation flying

Target Setup and Maneuver:
Tanker flies straight and level at constant airspeed.

Setup:
Begin in a precontact position (50 ft behind tanker boom with the pipper on the end of the boom) at test airspeed.

Maneuver:
Maintain a position 10-50 ft behind the boom with the pipper on a precise location (end of boom, light on end of boom, etc.). Change aim points on the boom periodically to evaluate repositioning capability. A suggested new aim point is the boom wingtips. The end of the boom can be used throughout the task if the boom operator makes small random horizontal and vertical movements with the boom.

Suggested Cooper-Harper Rating Performance Standards:
Desired: No objectionable PIOs. Maintain desired aim point within a 30 mil reticle for at least 50% of the task.

Adequate: Maintain desired aim point within a 50 mil reticle for at least 50% of the task.

Comments and Notes:
1. Tracking with a fixed mil tolerance is very dependent upon range between the aircraft and the boom.

2. The maneuver can incorporate use of the throttles or they can be isolated from the task. A pure tracking task can be accomplished by having a second pilot control the throttles while the evaluation pilot concentrates on tracking. The tracking capabilities can be severely degraded by requiring the pilot to also control range to the target.

3. Range control in the simulation was difficult due to the lack of closure cues. Pilots often devoted more time to range control than pipper tracking.

4. Test should be flown in non-turbulent conditions.

Potential Maneuver Variations

Variation A:
Target Setup and Maneuver:
The tanker can maintain a 30° bank turn to allow tracking while in a turn. Alternatively, the tanker can transition from right to left 30° banked turns.

Variation B:
Maneuver:
Range can also be eliminated from the task by starting out at 500-1000 ft behind the tanker and setting a known airspeed. Track the boom as the range decreases until in precontact position. Then reduce power and track as range increases again. When flying an aircraft with poor tracking characteristics, a potential measure of merit is the minimum range that tracking is possible within a set mil tolerance.

STEM 19: Tracking in Power Approach

The Tracking in Power Approach Maneuver is included as a method to evaluate Power Approach (PA) flying qualities at a safe altitude prior to conducting any demanding landing tasks. It requires the evaluation pilot to track a target that is making turns. This is used to help evaluate the ability to recorrect onto the glide slope precisely and quickly. Tracking in Power Approach was an existing maneuver but was further tested here for validation and because it may not be a well recognized evaluation maneuver. In particular, the maneuver was used on the F-15 STOL and Maneuvering Technology Demonstrator (S/MTD) program. During the STEMS development, the Tracking in Power Approach maneuver was tested with both fighter and transport aircraft models. Different target profiles were used for each aircraft class to represent the maneuvering requirements. This maneuver was used to evaluate variations in CAP, short period damping, roll mode time constant, and roll sensitivity. The maneuver provided a valuable evaluation for the fighter model, but it seemed to require a relatively large change in transport dynamics to result in any significant change. As a result, additional maneuver development is suggested before using this maneuver for transport aircraft. The target profile for the transport testing should potentially be more aggressive than the 15° heading change every 15 sec that was tested. In fact, the target profile may need to be more aggressive for both the fighter and transport tasks because both tasks tended to be somewhat benign. Also testing to date indicates that this may not be a valid maneuver for aircraft which are strongly backside at the nominal approach speed. The primary data generated from this maneuver appears to be pilot comments and ratings.

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STEM 19: Tracking in PA

Intent:
This manouver is intended to evaluate the precise tracking capabilities in a landing configuration. It can be performed at a safe altitude before precision landings are attempted but it tends to be a lower gain task. It generates primarily qualitative data in the form of pilot comments and ratings.

Applicable Classes and Flight Categories:
Class: all **Category:** C **Phase:** PA

Performance Objective	Aircraft Attributes	Operational Applications
Maintain precise control capabilities of an aircraft configured for PA.	Longitudinal flying qualities Lateral flying qualities Directional flying qualities Axial flying qualities Multi-axis flying qualities Frontside/backside operation	Precision landing

Target Setup and Maneuver:
Begin in straight and level flight at 15000 ft altitude at the approach speed of the test configuration. Begin 1500 ft directly ahead of the test aircraft. Perform gradual S turns with periods of straight flight between turns. Maintain constant altitude during the maneuver.

Setup:
Begin in PA configuration on approach speed and with a thrust for level flight throttle setting.

Maneuver:
Select specific reference points on the target aircraft and track with a 10 mil reticle. Aim point repositions on the target aircraft can also be exercised during the maneuver.

Suggested Cooper-Harper Rating Performance Standards:

Desired: No PIO. Pipper within ±5 mils of aim point 50% of the task and within ±25 mils the remainder of the task.

Adequate: Pipper within ±5 mils of aim point 10% of the task and within ±25 mils the remainder of the task.

Comments and Notes:
1. Different target profiles were required for variations in aircraft class. The target for the fighter aircraft performed a 30° heading change every 20 sec with periods of straight flight between Smaller heading changes were needed for the transport aircraft. The target for the transport aircraft performed a 15° heading change every 15 sec. A more rapidly moving target may be useful to increase the pilot gain and workload to expose deficiencies better.

2. The Cooper-Harper Rating performance criteria could be redefined by allowing the target to reach the new heading and subsequently rating how quickly the heading deviation could be corrected.

Potential Maneuver Variations

Variation A:
Target Setup and Maneuver:
Perform the same maneuvering as described above, but follow a typical glideslope instead of maintaining altitude.

STEM 20: Offset Approach to Landing

The Offset Approach to Landing maneuver is a well established technique to evaluate the flying qualities of an aircraft. It provides a very important evaluation of PA flying qualities and produces valuable comments. Several variations of this maneuver have been used in the past. As a result, this maneuver description is not an attempt to supersede that work, but it is meant to summarize the intent and give general guidelines for the maneuver. This maneuver can be applied to all aircraft classes, but the offsets and distances must be tailored to the aircraft type. Also, a valid and useful evaluation technique is to continue trying more demanding offsets until problems arise. The offset required in simulation may be more severe than desired in-flight because of safety-of-flight considerations and the naturally increased pilot gains for in-flight evaluations. Finally, the Cooper-Harper Rating performance criteria should be based on the aircraft type. The desired and adequate landing regions should be based on the intended mission and aircraft class such as Short Takeoff and Landing (STOL), Conventional takeoff and Landing (CTOL), fighter, transport, etc.

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STEM 20: Offset Approach to Landing

Intent:
This maneuver provides a demanding flying qualities task to test the ability to control flight path and speed while the aircraft is configured for approach. The data obtained is primarily qualitative in nature.

Applicable Classes and Flight Categories:
Class: all **Category:** A **Phase:** PA

Performance Objective	Aircraft Attributes	Operational Applications
Maintain ability to precisely control flight path and speed in a landing configuration.	Longitudinal flying qualities Lateral flying qualities Directional flying qualities Axial flying qualities Multi-axis flying qualities PIO tendencies Maneuverability Frontside/backside operation	Breakout at minimums off center Side-step approach and landing

Setup:
Begin 0.6 nm short of touchdown point, 0.14 nm right of centerline, 200 ft AGL, on approach speed, on correct flight path angle.

Maneuver:
Attempt to correct and land on speed at touchdown point with the proper heading. Try to maintain desired glide slope throughout maneuver.

Suggested Cooper-Harper Rating Performance Standards:
The following criteria may need refinement based on the aircraft class and precision desired.
Desired: Accomplish touchdown within a 20 ft wide by 60 ft long aiming box.

Adequate: Accomplish touchdown within a 50 ft wide by 100 ft long box.

Comments and Notes:
1. Also must conduct maneuver in turbulence, gusts, and wind shears.
2. The initial geometry to begin the correction to the runway may need to be less severe for in-flight testing than is used for simulation. Also modifications to the initial geometry are needed based on aircraft class (the geometry shown is for class IV aircraft).

Potential Maneuver Variations

Variation A:
Setup:
Variations in initial offset and distance from desired touchdown point can be tested to determine the most aggressive correction that can be made successfully.

Variation B:
Setup and Maneuver:
Require a curvilinear approach path instead of an straight offset approach.

Variation C:
Maneuver:
Require the pilot to reconfigure the aircraft to the approach configuration at the beginning of the task. This would potentially expose problems in transients between configurations.

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