INSTRUMENTATION AND TELEMETRY SYSTEMS FOR FREE-FLIGHT DROP MODEL TESTING

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ABSTRACT

This paper presents instrumentation and telemetry system techniques used in free-flight research drop model testing at the NASA Langley Research Center. The free-flight drop model test technique is used to conduct flight dynamics research of high performance aircraft using dynamically scaled models. The free-flight drop model flight testing supplements research using computer analysis and wind tunnel testing. The drop models are scaled to approximately 20% of the size of the actual aircraft. This paper presents an introduction to the Free-Flight Drop Model Program which will be followed by a description of the current instrumentation and telemetry systems used at the NASA Langley Research Center, Plum Tree Test Site. The paper describes three telemetry downlinks used to acquire the data, video, and radar tracking information from the model. Also described are two telemetry uplinks, one used to fly the model employing a ground based flight control computer and a second to activate commands for visual tracking and parachute recovery of the model. The paper concludes with a discussion of free-flight drop model instrumentation and telemetry system development currently in progress for future drop model projects at the NASA Langley Research Center.

KEYWORDS

Instrumentation, Telemetry, Free-Flight Drop Model

INTRODUCTION

NASA Langley Research Center has conducted free-flight drop model testing at the Plum Tree Test Site in Poquoson, Virginia over the last 2 decades. Drop model testing is a technique used to conduct flight dynamics research of high performance aircraft, and is used to augment the research conducted using wind tunnels and computer simulations. Aircraft can be tested in wind tunnels at high angles of attack up to the point of stall and subsequent departure into a spin, and in vertical wind tunnels this can be extended into fully developed spins. The free-flight drop model test technique provides a research vehicle that bridges the gap between stall and subsequent departure into a spin and a fully developed spin as illustrated in figure 1. The free-flight drop model test technique provides a research vehicle that can be used to study the post-stall dynamics of high performance aircraft.[1]

Drop models are typically 1/5 scale models of various high performance aircraft. The models are constructed of aluminum frames and bulkheads, with a fiberglass shell formed to the shape of the aircraft under study. The X-31 drop model that is currently being tested is shown in figure 2. The 27-percent scale model weighs in excess of five hundred pounds and is flown with a closed loop control system that emulates the system used in the full scale aircraft. The models are prepared for flight at the NASA Plum Tree facility and then attached to a helicopter as shown in figure 3. The model is carried to an altitude of approximately 12000 feet and dropped for the flight. When the model is dropped from this altitude, flight times in excess of 120 seconds can be achieved. Once the planned maneuvers are completed, the flight is terminated by flying the model over a suitable landing area on the Plum Tree range. A frequency modulated (FM) command system is then used to pyrotechnically deploy an onboard recovery parachute.

SYSTEM OVERVIEW

The drop model system is composed of the airborne system and the ground system. The airborne system includes the instrumentation system, the control system; the radio frequency (RF) transmitters, receivers, and antennas; and a radar transponder and video camera. The model electronic systems are powered by rechargeable nickel-cadmium batteries. Separate battery packs are used to power the instrumentation system, the servo actuator and control system and the pyrotechnic systems used to deploy the parachute recovery system. An overall operational illustration of these systems is shown in figure 4. A close-up view of the test facilities is shown in figure 5. The ground system is comprised of a tracker system, an instrumentation trailer, and a command and control trailer. The model's flight is monitored by the pilot at the flight control station in the command trailer. The pilot provides the stick inputs to the flight control computer (FCC) during the flight to control the model's location on the range and to fly the desired flight profile. The ground based FCC uses the pilots stick inputs along with the data telemetered from the model to implement control laws used to generate the control surface commands to fly the model. The commands are then telemetered to the model to close the loop on the control system. The airborne and ground instrumentation and telemetry system used to perform these tasks are described in the following sections.[2]

AIRBORNE SYSTEM

The recently upgraded airborne system including instrumentation, telemetry systems, and pulse code modulated (PCM) and FM command system electronics used in the X-31 drop model are illustrated in figure 6. A sample list of the model state and control information is presented in table 1. The onboard sensors provide analog outputs that are processed by a signal conditioner to achieve amplification, level shifting, filtering, etc., as needed to provide a 0-5 Volt level for input to a new microprocessor controlled miniature 64 channel, 12 bit PCM encoder. The PCM data is routed to an L-band FM transmitter for transmission to the ground. A printed circuit transmitting/receiving antenna array system that conforms to the interior of the nose of the X-31 model was designed, fabricated, and tested at NASA Langley Research Center.

The parachute commands and flight control commands are transmitted from the ground using two S-band transmitters. The commands are received by the onboard antenna and preamplified for routing to the receivers and decoders. The flight control commands are received by an onboard S-band receiver and processed by a new microprocessor controlled miniature 12 bit PCM decoder. The PCM decoder analog outputs control the various surface actuators; and the discrete outputs control the gyro caging commands for recently installed attitude gyro's and deployment/retraction of speedbrakes, etc. The parachute recovery and tracking smoke command signals are telemetered on the other S-band up-link. The relay outputs of the command decoder are used to activate the mortar charge to initiate the parachute deployment. The command decoder has a 100 ms delay timer installed in the relay circuit to prevent short duration telemetry system drop-outs from accidentally deploying the parachute. As an additional safety precaution a solid state timer circuit disables the parachute mortar until 10 seconds after model separation from the helicopter, thereby allowing the model to clear the helicopter before the parachute can be deployed. The FM decoder relay outputs also control the voltages that initiate a pyrotechnic smoke generator used to assist in visually tracking the model during the flight.

GROUND SYSTEMS

The recently upgraded free-flight drop model ground based instrumentation and telemetry systems are illustrated in figure 7. The model state information is telemetered down on a Bi-Phase-L PCM data link operating at 252 K bits/second using a L-band transmitter and is received by a tracker mounted ground antenna and downconverted to P-band for transmission to a FM receiver in the instrumentation trailer. The PCM data stream is recorded on an analog tape recorder for post flight data reduction, and is also routed to a smart PCM decoder for decoding, display, and conversion to analog outputs. The analog outputs from the PCM decoder are routed to digital to analog (D/A) converters for input to the ground based FCC, to real-time chart recorders for use during the research flights, and to a Heads-Up-Display Computer to generate the displays used by the pilot to assist in controlling the model during the flights. In addition to the decoded downlink data from the model, the analog to digital (A/D) converters also convert the analog voltages from the pilot control sticks for input to the FCC. The FCC generates the computed control surface position commands which are output by the FCC D/A converters for encoding and transmission to the model.

The FCC command data used to fly the model is encoded, along with discrete data used to control various model functions during flights, by a 21 channel 12 bit PCM encoder that is operating at 252 K bits/second. An example of the channel assignments which are used on the current model is shown in table #2. The encoder generates a Bi-Phase-L PCM data stream that is transmitted to the model using an S-band FM transmitter. The recovery parachute commands and the smoke commands, are activated by the use of a separate telemetry system. The parachute deployment commands are activated by either the pilot, the flight engineer or the flight coordinator. Since the parachute is used to recover the model at the end of the flight the parachute commands are considered to be the most important and are redundantly encoded as two discrete tones using IRIG command channels which are transmitted on a separate S-band link. In addition to being redundantly encoded, the command tones are also commanded during the flight to not deploy the chute, so that in the event of a ground system or telemetry failure the parachute will be deployed and the model recovered. The smoke command is encoded using and IRIG command channel and is also transmitted on a S-band telemetry link.[3]

The pilot is provided high resolution video images of the free-flight drop model from tracker mounted cameras which provide a ground to air view, and a pilots eye view of the flight from an onboard cockpit mounted camera. The onboard camera data is telemetered down using an S-band video transmitter. In addition, a computer generated geographical map with an overlay showing heading and the position of the model on the range is provided to the pilot during the flights.

The FCC computes the spatial location of the model using the slant range, azimuth, and elevation data. The slant range data is obtained from a tracking system which uses a radar transponder in the model and a radar interrogator (Receiver Transmitter) and processor located in the instrumentation trailer. The azimuth and elevation data is obtained from position encoders mounted on one of the ground based trackers. This data is used by the FCC to compute the resulting x, y, and altitude information which is then presented on a video display in the pilot control station for use by the model pilot and flight engineer during the flights. All pertinent video signals are recorded on S-VHS video and U-Matic recorders and are used to assist in post-flight data analysis and for documentation.

PREFLIGHT CALIBRATION

A preflight calibration and system check is performed on the instrumentation and telemetry systems prior to each flight. All of the model electronic systems are energized. The uplink command system is activated and the control surfaces are commanded to several positions by the ground based FCC. The output of the downlink PCM decoder is monitored to verify that each control surface control position transducer (CPT) indicates the level corresponding to the commanded control system deflection. This verifies the operation of both the uplink command system and the corresponding downlink data channel. Two angle-of-attack sensors and one angle-of-sideslip sensor are also checked at several positions. In addition to the control surfaces and flow direction sensors, other analog data channels are observed in their ambient position and verified on the downlink PCM decoder. The discrete uplink channels are activated and the model system response is verified. Each downlink discrete channel is checked by performing the required action on the model and observing the change on the downlink PCM decoder discrete channel.

Once the model is mounted on the helicopter the instrumentation and telemetry systems are energized and a three-point calibration is performed on all the analog downlink data channels. This calibration is recorded on the ground-based recorder for use during the data reduction process.

FUTURE DEVELOPMENT

Future development plans call for a significant improvement in the ground based instrumentation and control system electronics by replacing the current analog interfaces that are shown in figure 7. This will be accomplished by upgrading the FCC to a computer that uses a Virtual Memory Extension (VME) bus system, and replacing the current uplink encoder and downlink decoder with VME compatible plug-in card encoder and decoder modules installed in a VME expansion chassis as shown in figure 8. In addition to replacing the PCM encoder and decoder, the data will be distributed to the other computers in the system using a local area network. These changes will significantly reduce the system wiring in the instrumentation and command trailers and allow for improved speed and accuracy in the system communications.

The changes planned for the model include the addition of a second video downlink from the model to allow for flow visualization and onboard systems monitoring. This video link will be added using a S-band link to minimize the chance of interference with other frequencies on the model and particularly the FM command S-band link used to deploy the parachute. In addition, the second video transmitter will utilize a subcarrier to send the data from an onboard Global Positioning System (GPS) receiver to the ground to investigate the use of the GPS for tracking the model.

CONCLUSION

Versatile instrumentation and telemetry systems were developed at NASA Langley Research Center that are ideally suited to conduct free-flight drop model research testing utilizing a closed loop control system with the flight control computer on the ground. The system reliability, ease and speed of reconfiguring, and the accuracy of the model state data were significantly improved by the application of a microprocessor controlled encoder and decoder in the model. Near term replacement of the A/D and D/A interfaces between the ground based FCC, and the downlink data decoder and uplink command encoder, with digital interfaces will further improve the system reliability, accuracy and noise rejection.

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TABLE # 1

SAMPLE PCM DOWNLINK
DATA CHANNELS

CHN. #	PARAMETER (ANALOG)	SAMPLE RATE (Hz)
1	Angle-of-Attack	1000
2	Sideslip Angle	1000
3	Canard Position	1000
4	Roll Attitude	200
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--	---	---
52	Airspeed	100
53	Discrete Data	
BIT	**PARAMETER (DISCRETE)**	**SAMPLE RATE (Hz)**
1	Drop Pin Event	100
2	Hatch Sensor	100
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12	Gyro #1 Status	100

TABLE # 2

SAMPLE PCM UPLINK
DATA CHANNELS

CHN. #	PARAMETER (ANALOG)
1	Canard Command
2	Rt. Flap Command
3	Lft. Flap Command
4	Rudder Command
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--	---
18	FCS Mode
19	Inlet Lip Command
BIT	**PARAMETER (DISCRETE)**
1	Gyro Cage Command
2	Boom Rotate Command
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12	Speed Brake Command

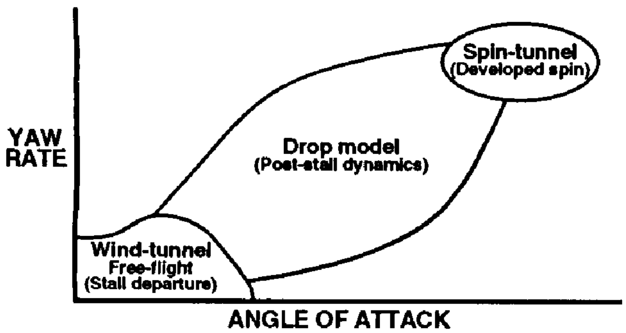


Figure 1. High AOA Test Technique

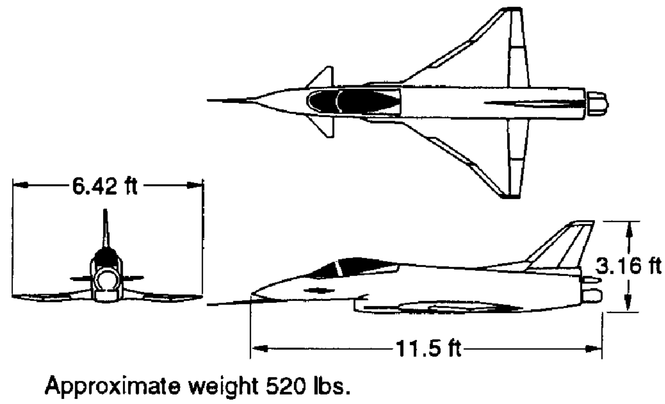


Figure 2. X-31 Drop Model Configuration

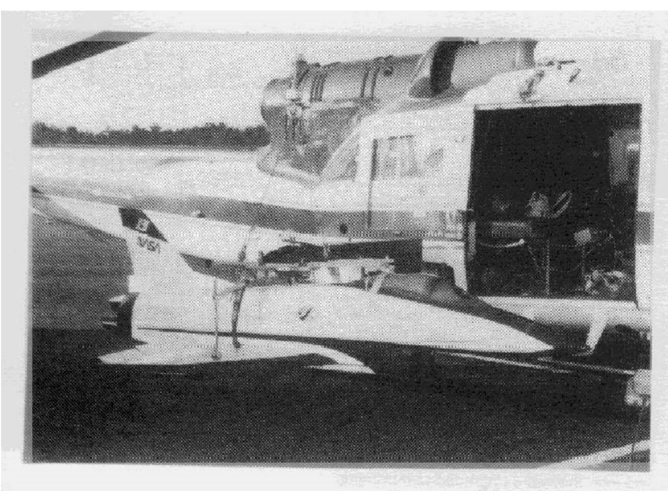


Figure 3. Model to Helicopter Attachment

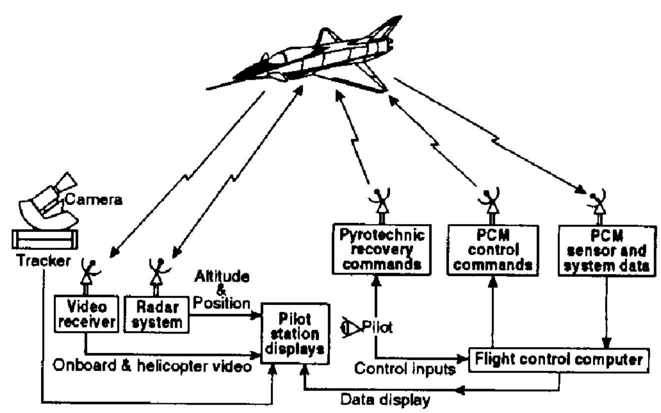


Figure 4. Overall Operation of Drop Model

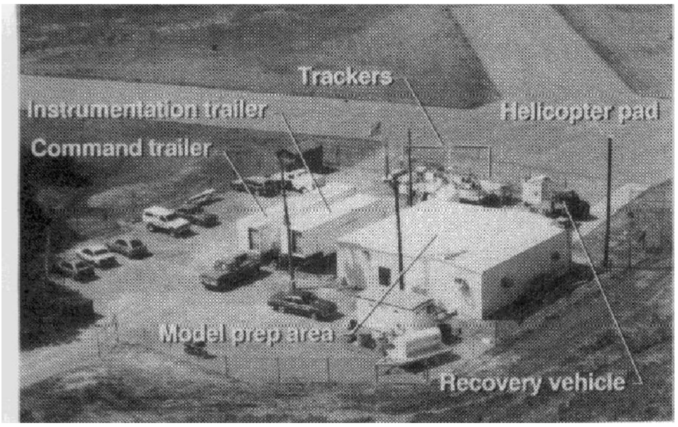


Figure 5. Test Facility

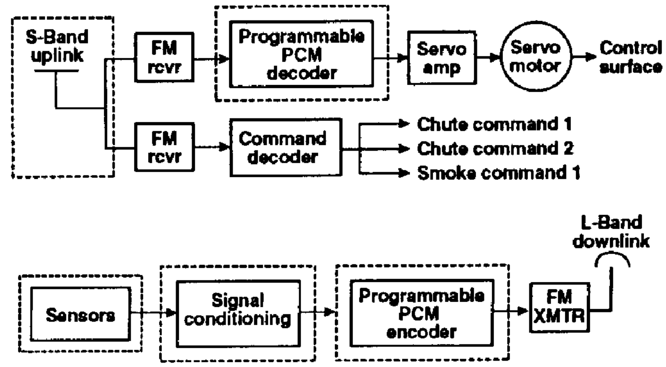
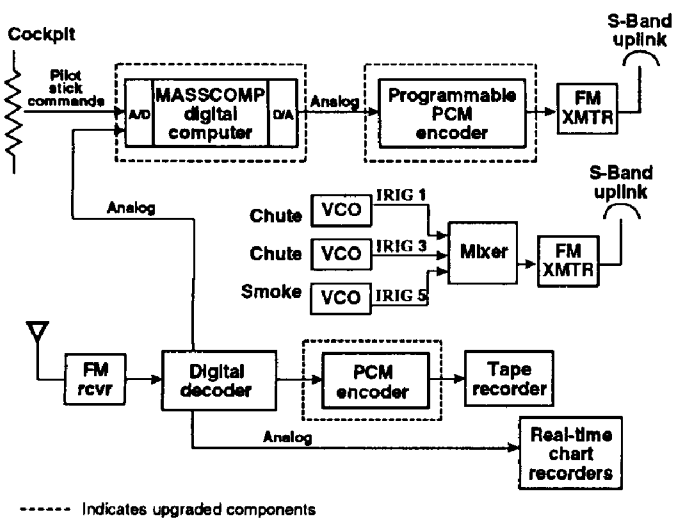


Figure 6. Airborne System Upgrade



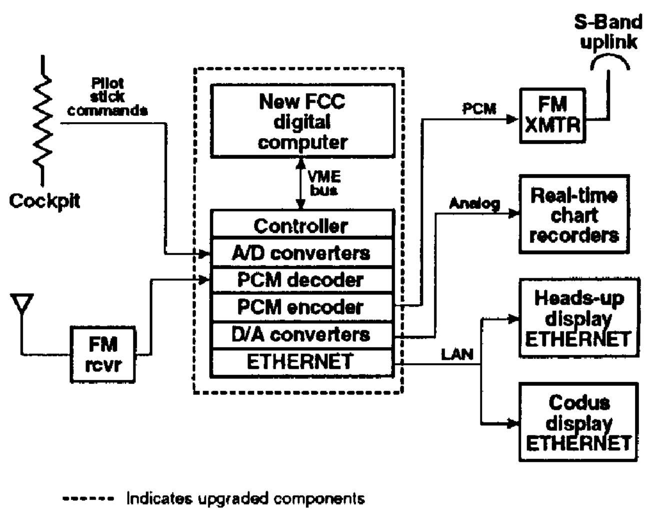


Figure 7. Ground System Upgrade **Figure 8. Future Ground System Development**