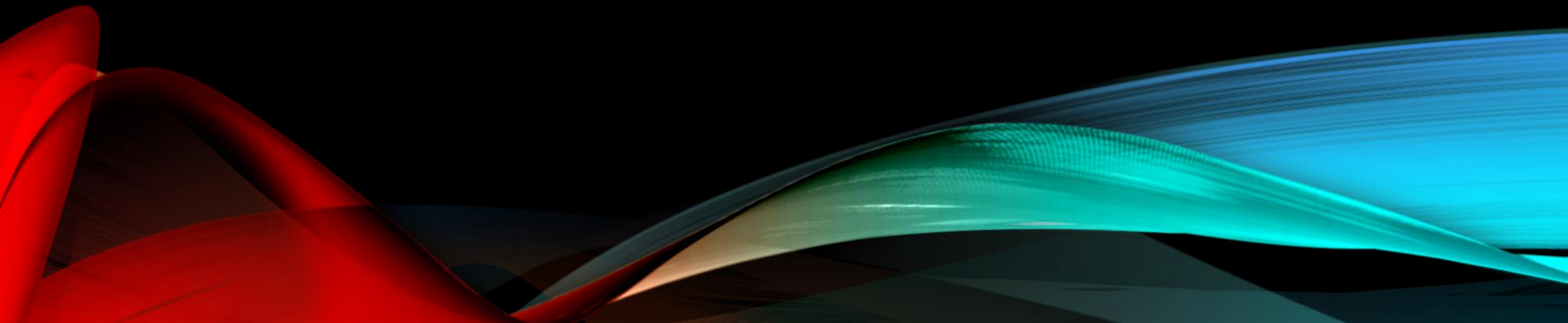
FUNDAMENTALS OF FLIGHT TESTING

Office of Integrity, Safety, and Compliance

Flight Operations

TABLE OF CONTENTS

EXPECTATIONS



AIRCRAFT READINESS

- Aircraft must be completely built and in the desired configuration for the test flight
- Checklists – list every procedure for every phase of flight
- Pilots have the right and duty to not fly unairworthy aircraft
- High build quality
  - Minimal flex in the structure
  - Tight tolerances in all components
  - Structure adequate for the mission
  - Overall high degree of craftsmanship

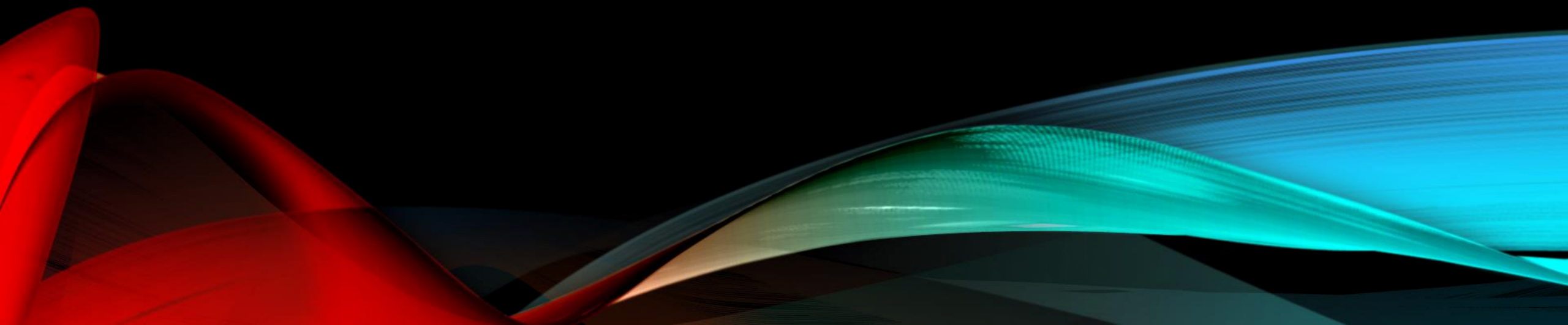
PREPARATION

- Time quoted by pilots is the time your aircraft should be completely ready. If we say meet at 1300, we expect you to be ready for a briefing at 1300 and in the air at 1305. Punctuality is expected.
- Ensure you have all components of the aircraft with you – if you forget stuff, we'll leave.
- Have test cards made (more detail later).

SAFETY AND COMPLIANCE

- Team must procure the following:
  - Permission to fly at test location
  - Safety plan to mitigate risk
  - Plan to be compliant with FAA, CU, local requirements

GOALS OF FLIGHT TEST



AT A HIGH LEVEL

- Validate aircraft performance
- Validate structural performance
- Validate avionics performance
- Identify and fix any design issues
- Ascertain handling qualities

TYPES OF TESTING TO PERFORM

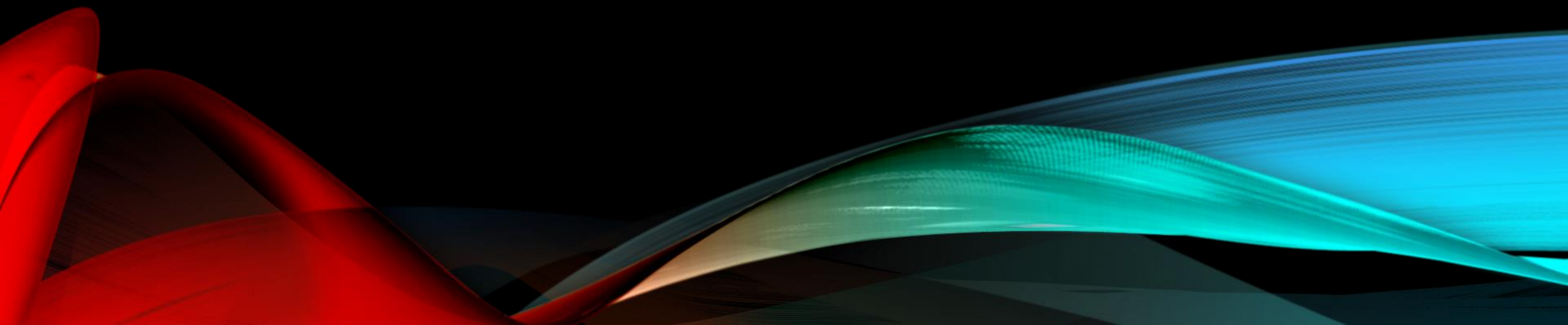
- Performance (climb rate, range, etc.)
  - Sample test: pilot maintains constant throttle setting and pitch, climbs from 100 to 400 feet. Time required is measured.
- Structure (aeroelasticity, structural integrity)
  - Sample test: pilot loads the aircraft by performing progressively steeper banked turns.
- Avionics/electronics
  - Sample test: in no-wind scenario, ensure airspeed matches groundspeed within a specified tolerance.
- Handling – more on this later
- Each category is not necessarily applicable. Design tests for *your* aircraft.

PERFORMANCE, STRUCTURE, AVIONICS TESTING

- Your test card should specify what maneuvers are needed for the test in question.
- In this case, the relevant parameters should be measured by onboard or ground-based sensors.
- Good idea to repeat maneuvers/tests several times.
- Test design is the responsibility of the engineers. Be systematic and thorough.

HANDLING QUALITY SCALES

Cooper-Harper, PIO



GENERAL NOTES ON HANDLING QUALITY

- An aircraft cannot be assigned an overall handling quality rating.
- Only specific, repeatable, well-defined maneuvers have a handling quality attached to them.
- Pilots might disagree on the precise handling quality rating but should generally agree on the rough rating.

COOPER-HARPER SCALE

- Rating from 1-10 based on mental workload, trust in aircraft, and situational awareness.
- 1 represents best case, 10 represents worst case.
- Generally, this is the most widely used scale.

COOPER-HARPER – MENTAL WORKLOAD

- CH of 1 represents an aircraft that requires minimal pilot attention to achieve the desired performance.
- CH of 5 represents an aircraft that performs adequately but only with a considerable amount of pilot attention.

COOPER-HARPER – TRUST IN AIRCRAFT

- CH of 1 represents a very predictable aircraft, and the pilot can be confident in predicting what flight control inputs are needed for a given maneuver.
- CH of 5 represents an aircraft with significant handling quirks such that a pilot's ability to predict the effect of control inputs is compromised.

COOPER-HARPER – SITUATIONAL AWARENESS

- CH of 1 represents an aircraft that requires only a small amount of pilot attention so that they can be fully aware of the situation.
- CH of 5 represents an aircraft that requires so much pilot attention that situational awareness is compromised considerably.

COOPER-HARPER 10-POINT SCALE

1. Pilot compensation not a factor for desired performance
2. Pilot compensation not a factor for desired performance
3. Minimal pilot compensation required for desired performance
4. Desired performance requires moderate pilot attention
5. Adequate performance requires considerable pilot attention
6. Adequate performance requires extensive pilot attention
7. Adequate performance not attainable within acceptable pilot workload; controllability not in question
8. Considerable pilot attention is required for control
9. Intense pilot concentration needed to maintain control
10. Control lost during some portion of the required operation

COOPER-HARPER IN GENERAL

- Mental workload, trust in aircraft, situational awareness all related.
- A predictable aircraft will not require much pilot attention, meaning the pilot can focus on situational awareness.
- An aircraft that scores well in one category should score well in the others.
- Make more objective based on flowchart on next slide.


1 Excellent, desirable Pilot compensation no factor
2 Good, neg. def. Pilot compensation no factor
3 Fair, some def. Minimal pilot compensation
Yes
Satisfactory without improvement?
No
Warrant improvement
4 Minor deficiencies Moderate pilot compensation
5 Moderate def. Considerable pilot compensation
6 Objectionable def. Extensive pilot compensation
Yes
Adequate performance attainable with tolerable pilot workload?
No
Require improvement
7 Major deficiencies Controllability not in question
8 Major deficiencies Lots of attn req'd for control
9 Major deficiencies Intense attn req'd for control
Yes
Is it controllable?
No
Mandatory improvement
10 Major deficiencies Loss of control expected
Pilot decisions

PILOT-INDUCTED OSCILLATION (PIO) SCALE

- Less common than Cooper-Harper.
- PIO are sustained and uncontrolled oscillations resulting from the pilot's efforts to control the aircraft.
- Example scenario: pitch-down attitude on landing, pull up sharply to correct for it, near a stall, pitch down again.

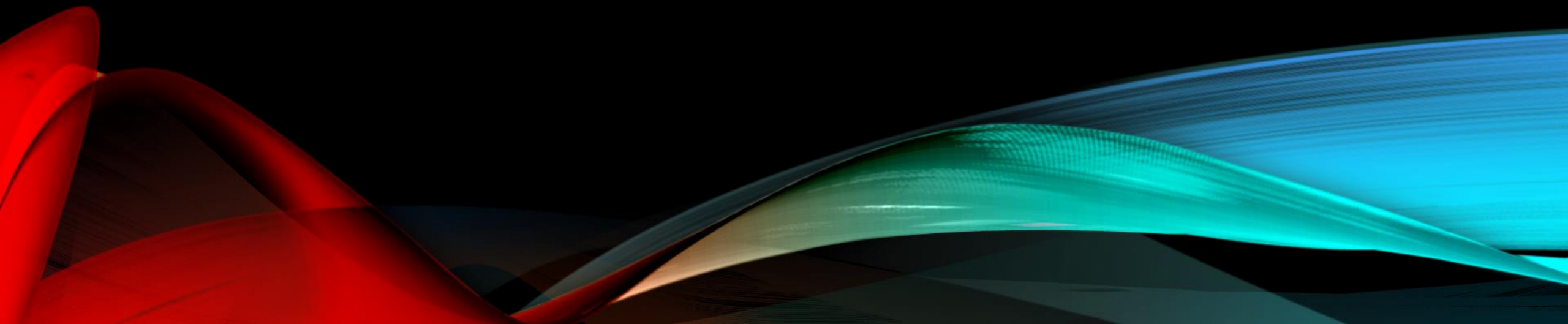
PIO 6-POINT SCALE

1. No oscillation or undesirable motions
2. No oscillation; undesirable motions don't interfere with task performance
3. No oscillation; undesirable motions do interfere with task performance
4. Oscillation, but not divergent
5. Divergent oscillation upon abrupt control input
6. Divergent oscillation upon first attempt to enter control loop

TIPS FOR HANDLING QUALITY SCALES

- Low scores (especially in PIO) can be a function of poor pilot ability. Use an experienced pilot to ensure the results are meaningful.
- Focus on handling quality for the most important maneuvers to your use case.

TEST CARDS



STRUCTURE OF A TEST CARD

- One test card per set of maneuvers.
- Information for each maneuver is a test point.

TEST POINT REQUIREMENTS

- Any procedures / maneuvers *outside of normal procedures* that need to be conducted in order to gather the required data.
- Note on the test card when the pilot needs to give a value for handing quality.

EXAMPLE SET OF TEST POINTS

- Takeoff rotation
  - Start data recorder
  - Set flaps to full
  - Rotate at 8 m/s IAS
  - Cooper-Harper rating
- Climb
  - Climb steadily from 100 ft AGL to 300 ft AGL while maintaining 75% thrust and the same airspeed
  - Cooper-Harper rating
  - Measure climb rate based on onboard barometer

GENERAL SUGGESTIONS

- Perform testing at CU South Boulder or Boulder Aeromodelling Society.
- Acquire AMA insurance.
- Normalize all data to standard sea level conditions.
- Follow procedures set out by OISC. Failure to do so can result in teams incurring personal liability.