Unmanned Aircraft Systems (UAS) Integration in the National Airspace System (NAS) Project

Automatic Execution of Collision Avoidance and Return to Course Analysis (D.6.20)

Experiment Review

Presented By
Garrett Sadler
Human Systems Integration

1 March 2019

Background

- Phase 1 of UAS DAA MOPS included Class I and Class II DAA systems
  - Class I – DAA-only (i.e., no collision avoidance)
  - Class II – DAA + TCAS II
- Phase 2 introduces Class III DAA systems
  - ACAS Xu provides both DAA and CA functionality
  - Minor modifications made for DAA
    - No DAA Warning
    - No Well Clear Recovery Guidance
- There is a need to develop Resolution Advisory (RA) display requirements for ACAS Xu
  - DAA requirements leveraged from the Phase 1 DAA MOPS
  - Vertical RA display guidance informed by TCAS
- Current gaps in display requirements:
  - How are horizontal and "blended" RAs presented?
  - How should automated ACAS functions be presented and behave?

Experiment Objective

- The engineering analysis will generate "canned" RAs rather than use Xu code, divided into two parts.

- Part 1 objectives:
  - Investigate the effects of various display configurations on pilot response to ACAS Xu RAs
    - Get pilot feedback on display and alerting guidance for ACAS Xu
    - Verify differential effects of RA alerting configurations
    - Inform design for ACAS Xu full mission HITL

- Part 2 objectives:
  - Investigate the effects of automating collision avoidance (CA) and return-to-course (RTC).
    - Use findings to inform optional automation requirements for SC-228
    - Examine pilot response to apparent automation failures

ACAS XU ENGINEERING ANALYSIS
PART 1 OVERVIEW

Part 1 Experimental Design

- Independent Variables (2-by-2, within-subjects)
  - Text (2 levels)
    - Text guidance provided
    - Text guidance absent
  - Blended-offset alerting (2 levels)
    - Basic aural alerts
    - Advanced aural alerts

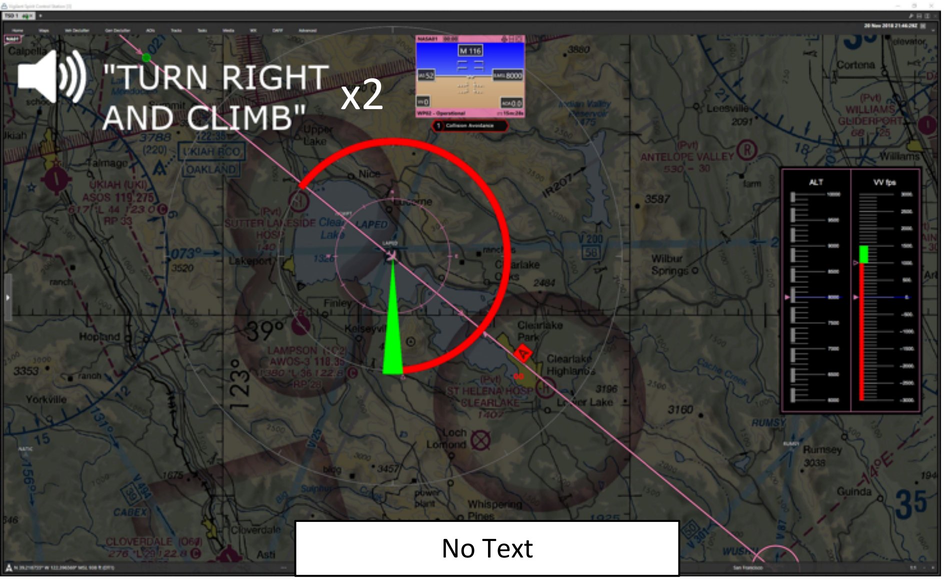
- Embedded Variable (within-trial)
  - RA type*
    - Vertical-only
    - Horizontal-only
    - Blended-simultaneous
    - Blended-offset

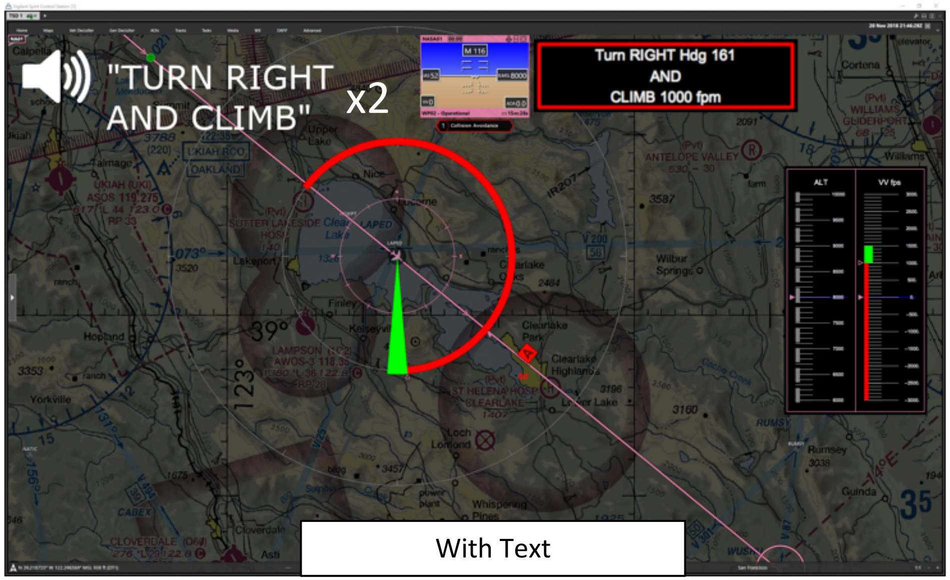
  (Horizontal-only, Blended-simultaneous, Blended-offset: Unique RAs to ACAS X)

*Note: to simplify our design we have not included RA reversal, strengthening, or multi-threat encounters. These cases may be examined in a upcoming study by the FAA.

Part 1 Experimental Design: Text IV Example

- Blended-simultaneous RA





Part 1 Experimental Design: Blended-Offset Alert IV Example

- Advanced behavior for blended-offset RAs
  - First RA issued normally (e.g., as a vertical or horizontal RA)
    - “Climb/Descend” x2
    - “Turn Right/Left” x2
  - Logic used to modify order and verbiage of second RA

- Example: Turn right RA followed 8 seconds later by climb RA
  - **Basic** aural alert:
    - First aural alert: “Turn Right” x2
    - Second aural alert: “Turn Right and Climb” x2
  - **Advanced** aural alert:
    - First aural alert: “Turn Right” x2
    - Second aural alert:
      - If target heading not achieved: “Climb and Turn Right” x2
      - If target heading achieved: “Climb and Maintain Heading” x2

Part 1 Experimental Design

- Dependent Variables
  - Response Time to RAs
    - Do they vary by RA type?
    - Do they vary by RA presentation?
  - Compliance rate
    - Did the RA display affect the participants' ability to successfully comply with RAs?
    - Diagnose instances of non-compliance
  - Subjective ratings
    - Workload (NASA TLX)
    - Post-Trial & Post-Sim Questionnaires
    - Post-Sim Debrief (open-ended)

Note: not assessing Loss of Well Clear/NMAC performance since we're scripting RAs and constraining their responses to DAA alerts.

Part 1 Hypotheses

- Research Question
  - How does the absence or presence of textual RA alerts affect pilot response to ACAS Xu advisories?
  - Can pilots comply with blended RAs with comparable performance to single-sense RAs?
    - Is performance affected by blended-offset alert variable?
- Expected Outcome
  - The presence of textual alerts will increase pilot accuracy in compliance with ACAS Xu RAs, particularly for blended RAs.
  - Pilots will be slower to respond to blended RAs.

ACAS XU ENGINEERING ANALYSIS PART 2 OVERVIEW

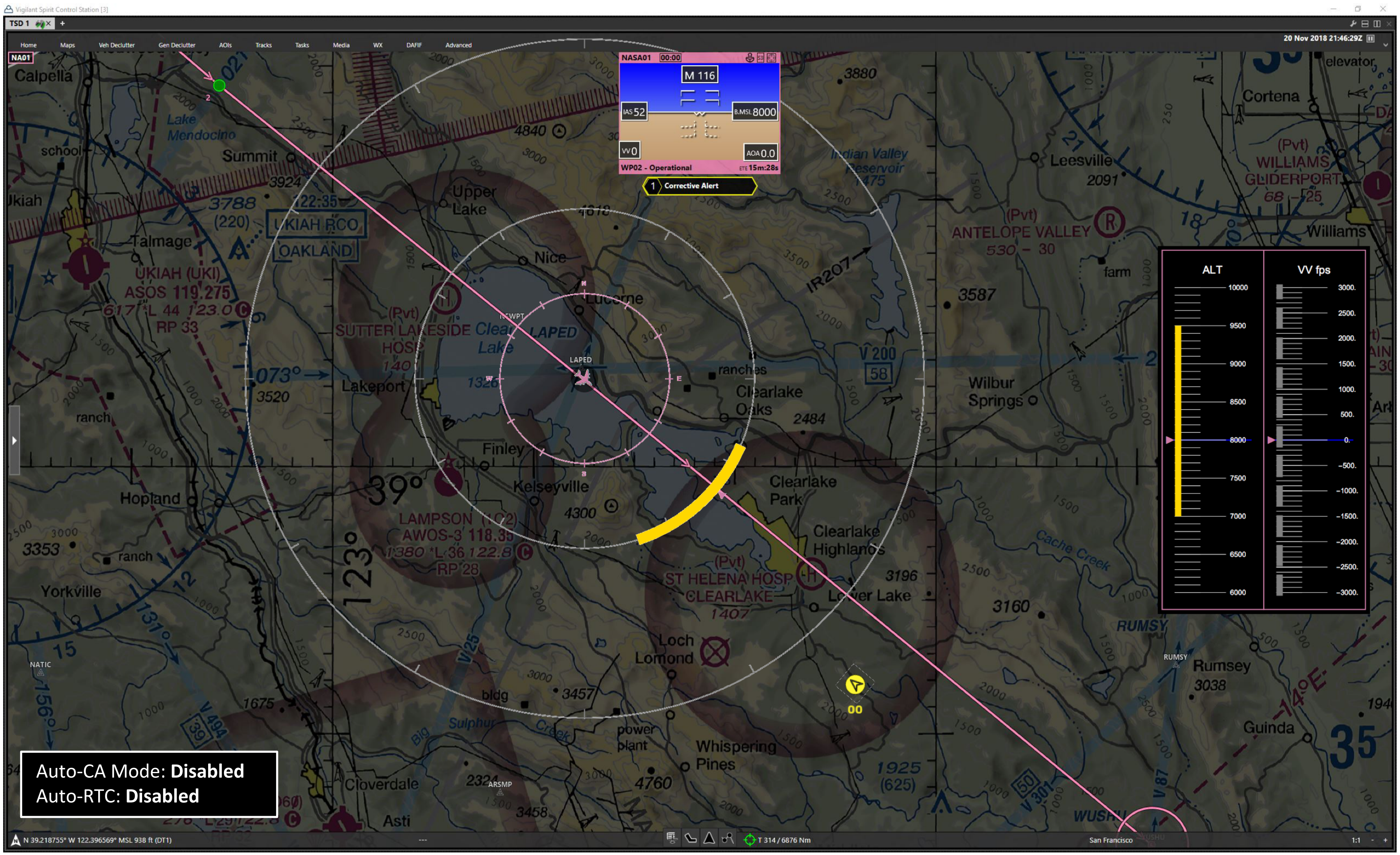
Part 2 Experimental Design

- Independent Variables
  - Automation Level (within-subjects, 3 levels)
    - Manual
      - Carries over preferred display (per pilot feedback) from Part 1
    - Auto Collision Avoidance (CA)
      - RA is auto-executed as soon as issued
      - Pilot can disengage (override) automation at discretion
    - Auto CA & Return-To-Course (RTC)
      - RTC is auto-executed as soon as Clear of Conflict (CoC) is declared
      - Pilot can disengage (override) automation at discretion

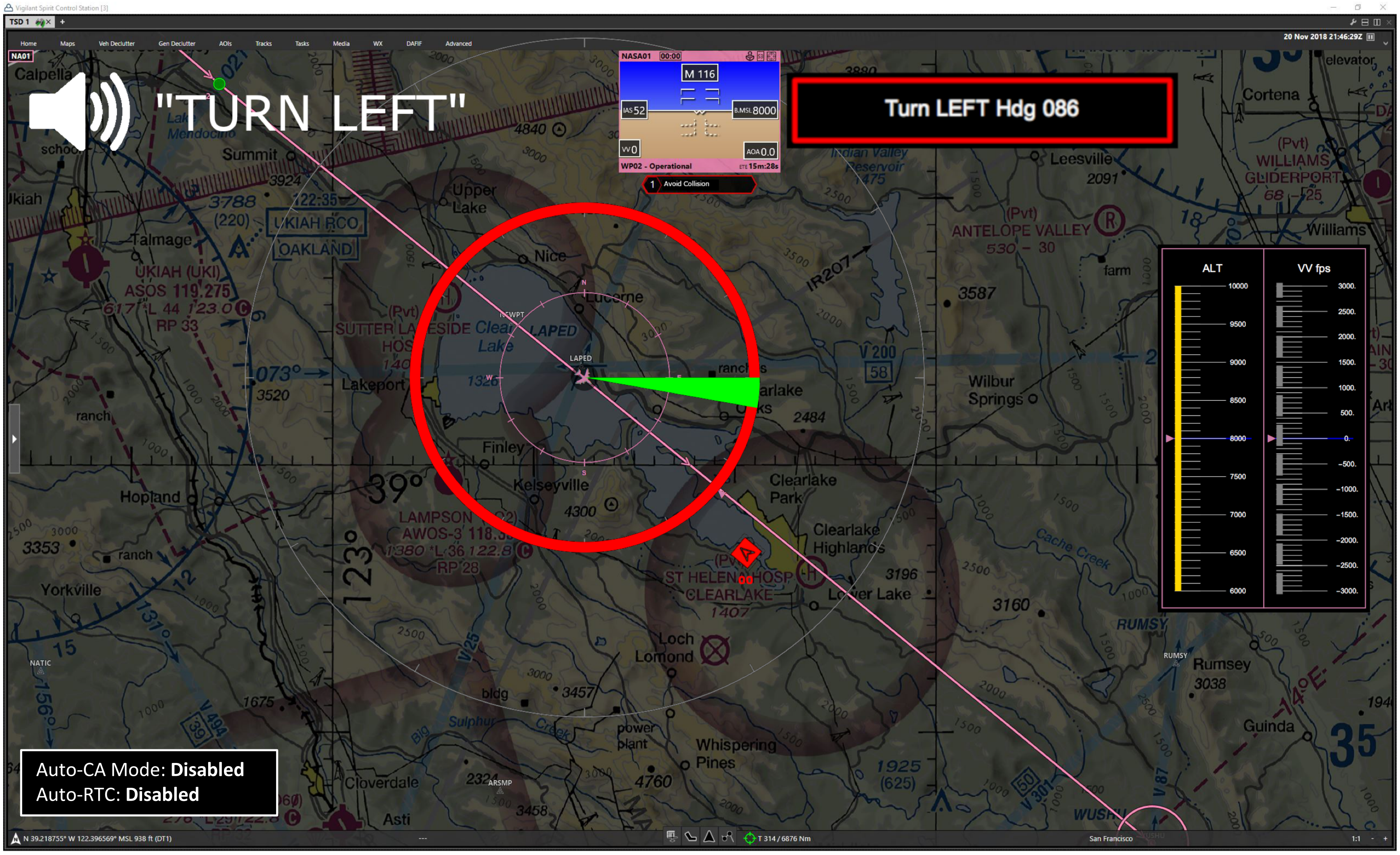
- Embedded Variable (within-trial)
  - RA type
    - Vertical-only
    - Horizontal-only
    - Blended-simultaneous
    - Blended -offset
  - Automation failure
    - Auto CA response fails to occur

MANUAL CA & RTC EXAMPLE

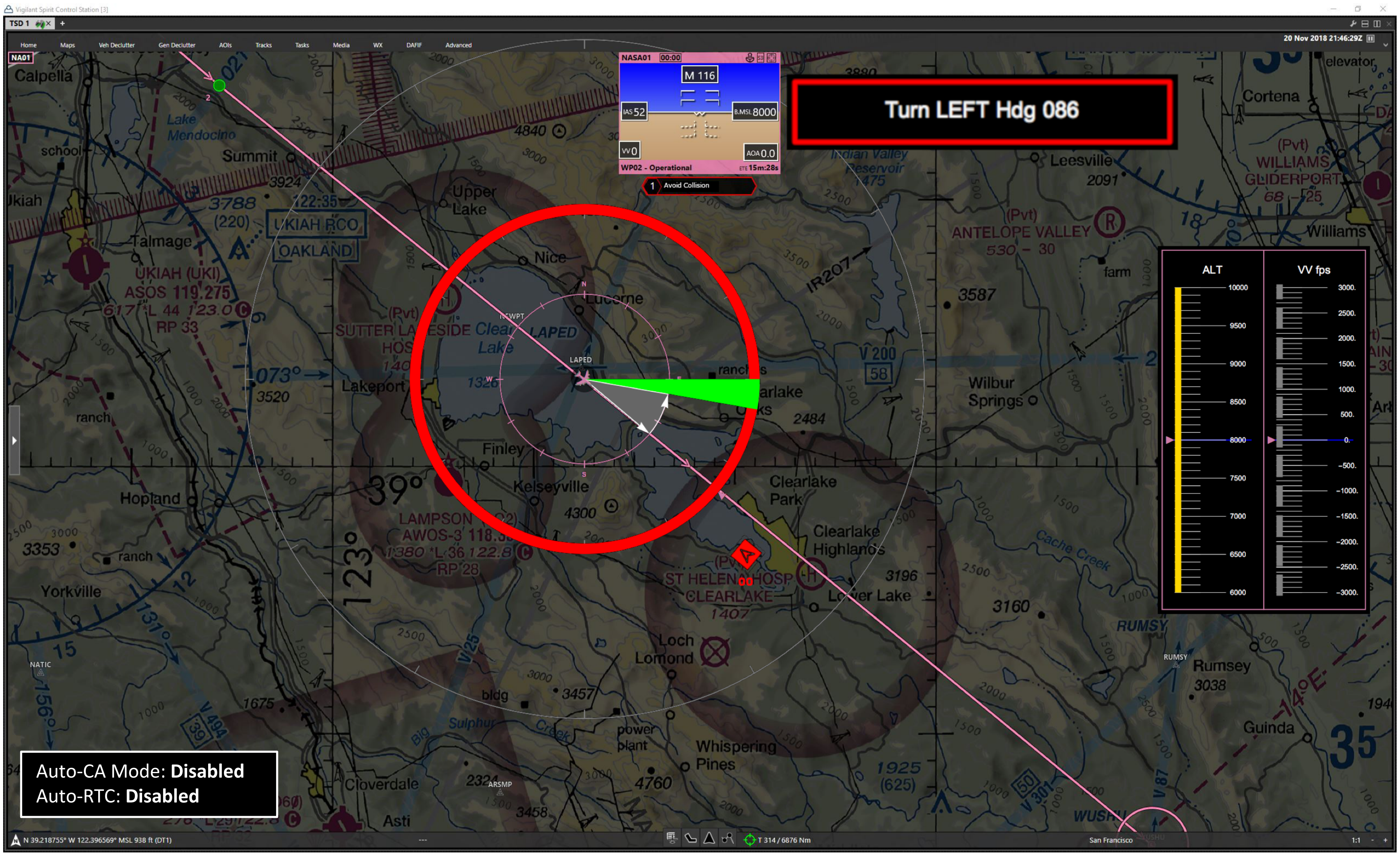
Manual – Prior to RA



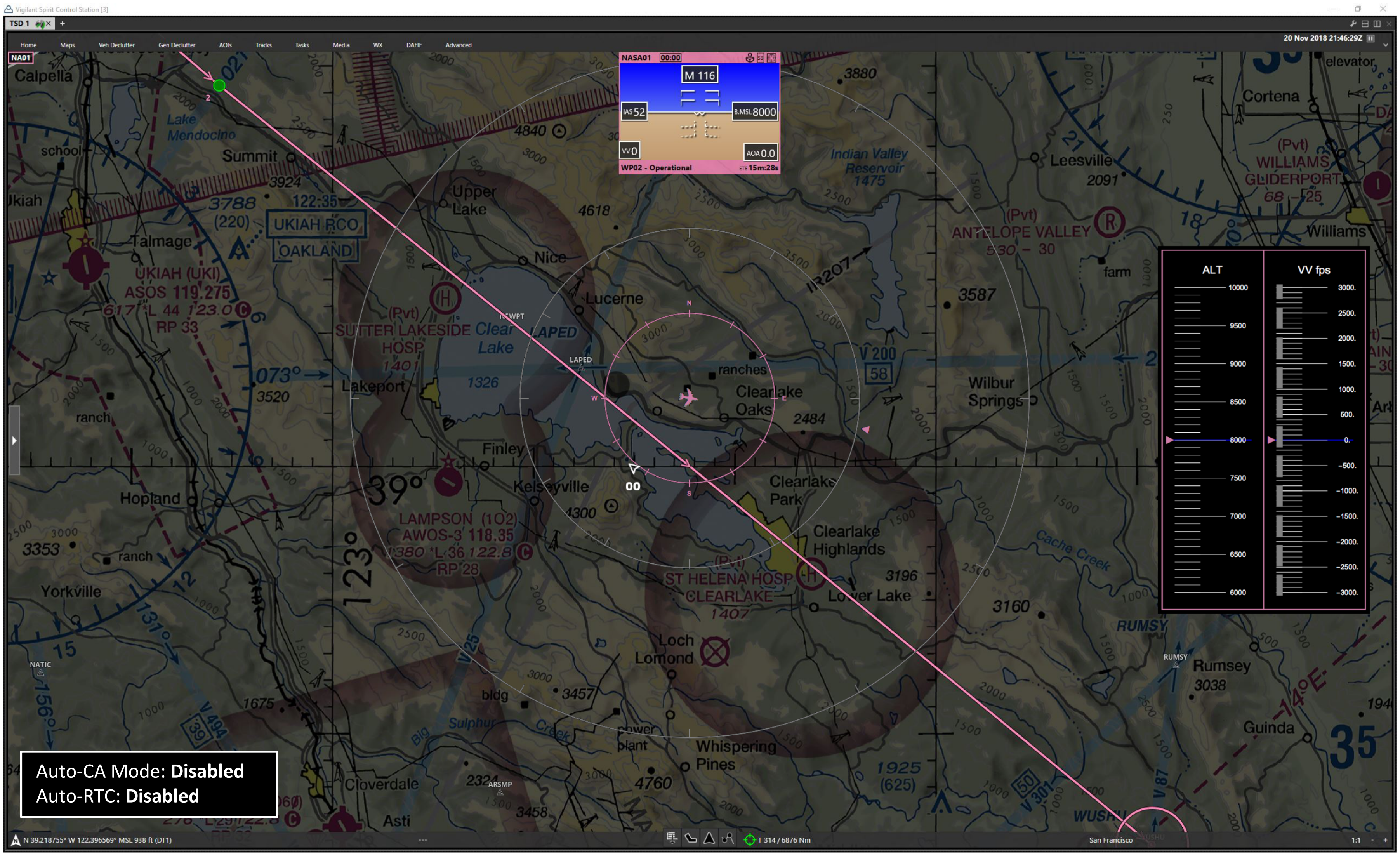
Manual – Horizontal RA Issued



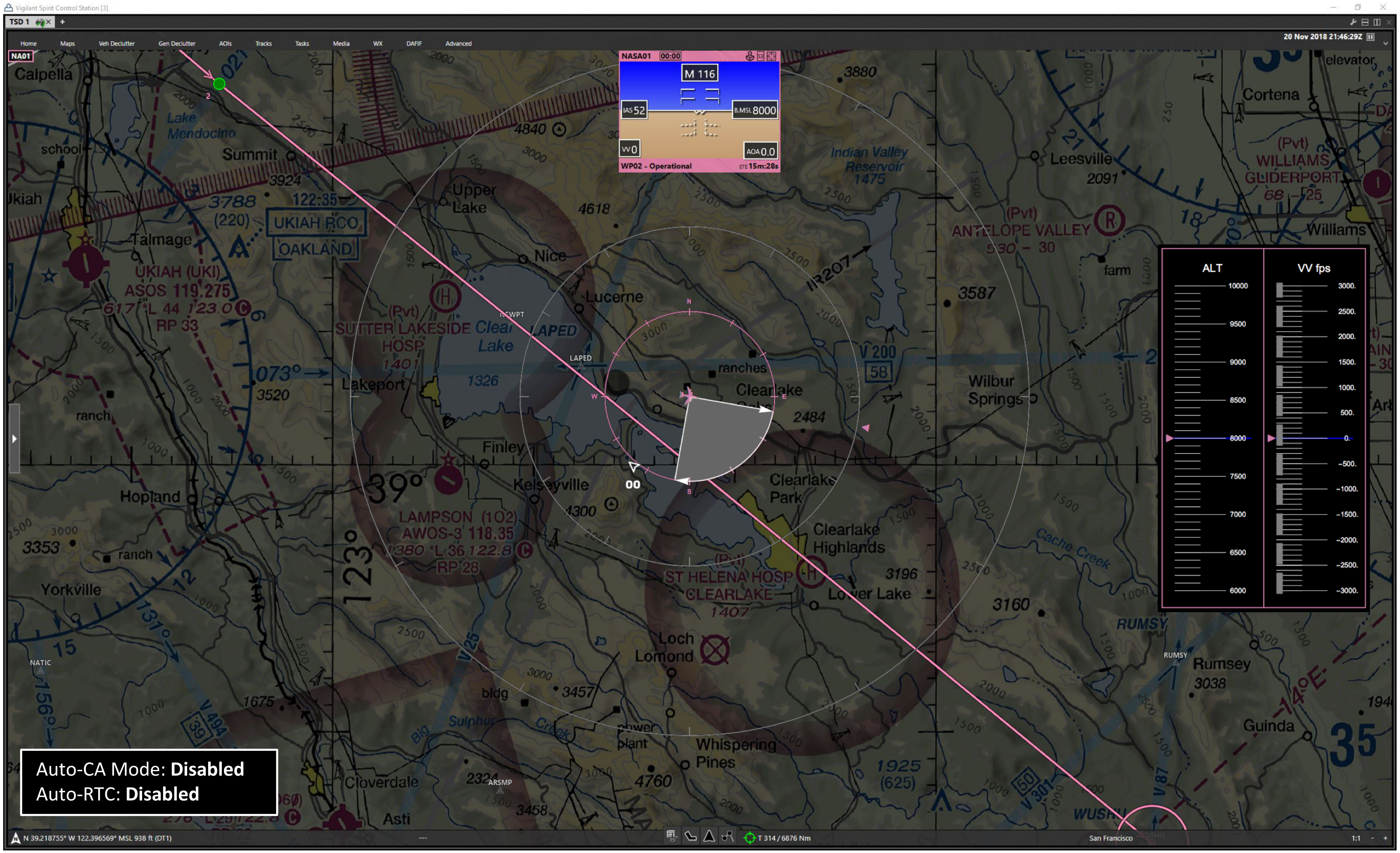
Manual – PIC Modifying Heading



Manual – Clear of Conflict

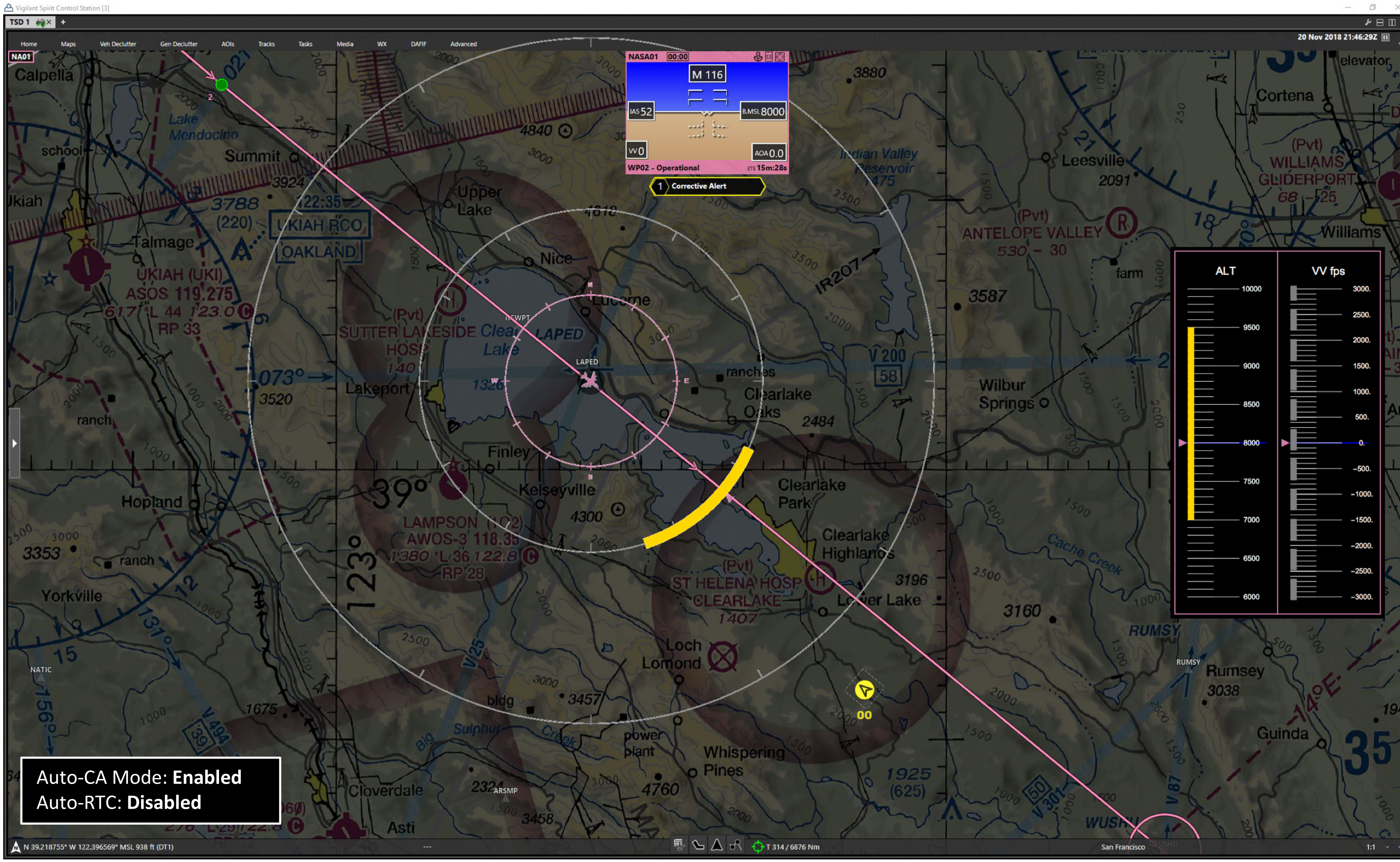


Manual – PIC Performs RTC

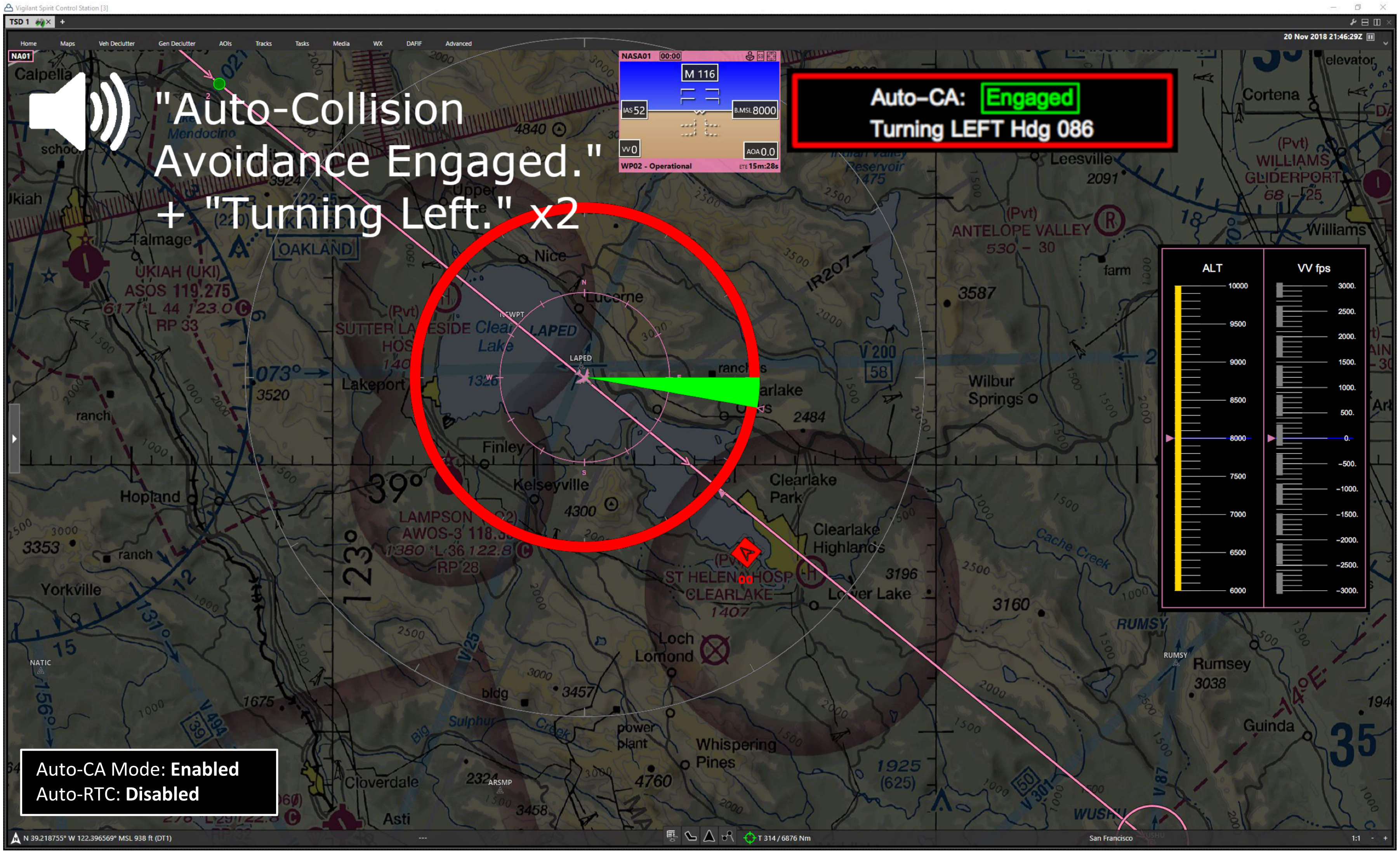


AUTO CA & MANUAL RTC EXAMPLE

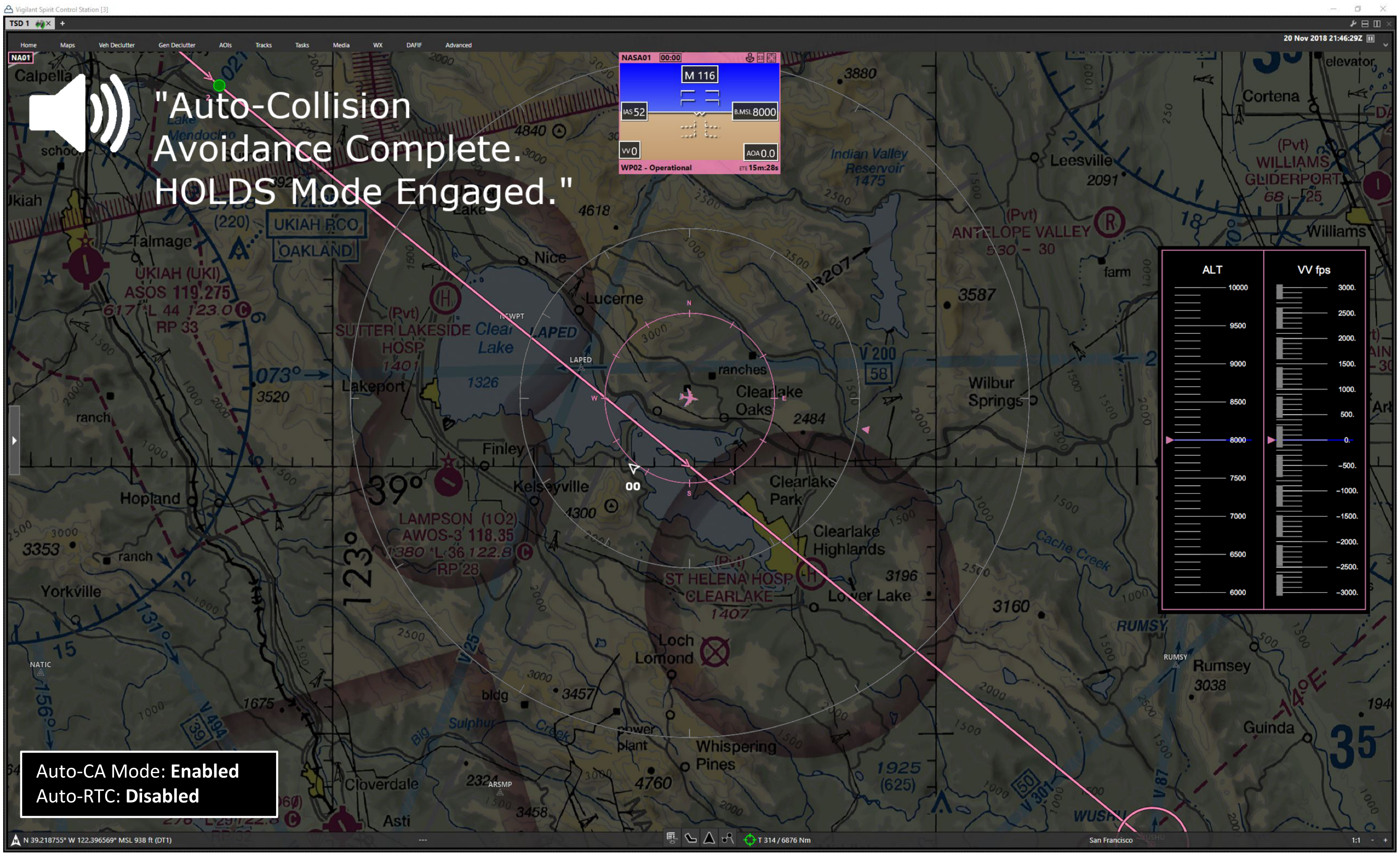
Auto CA Only – Prior to RA



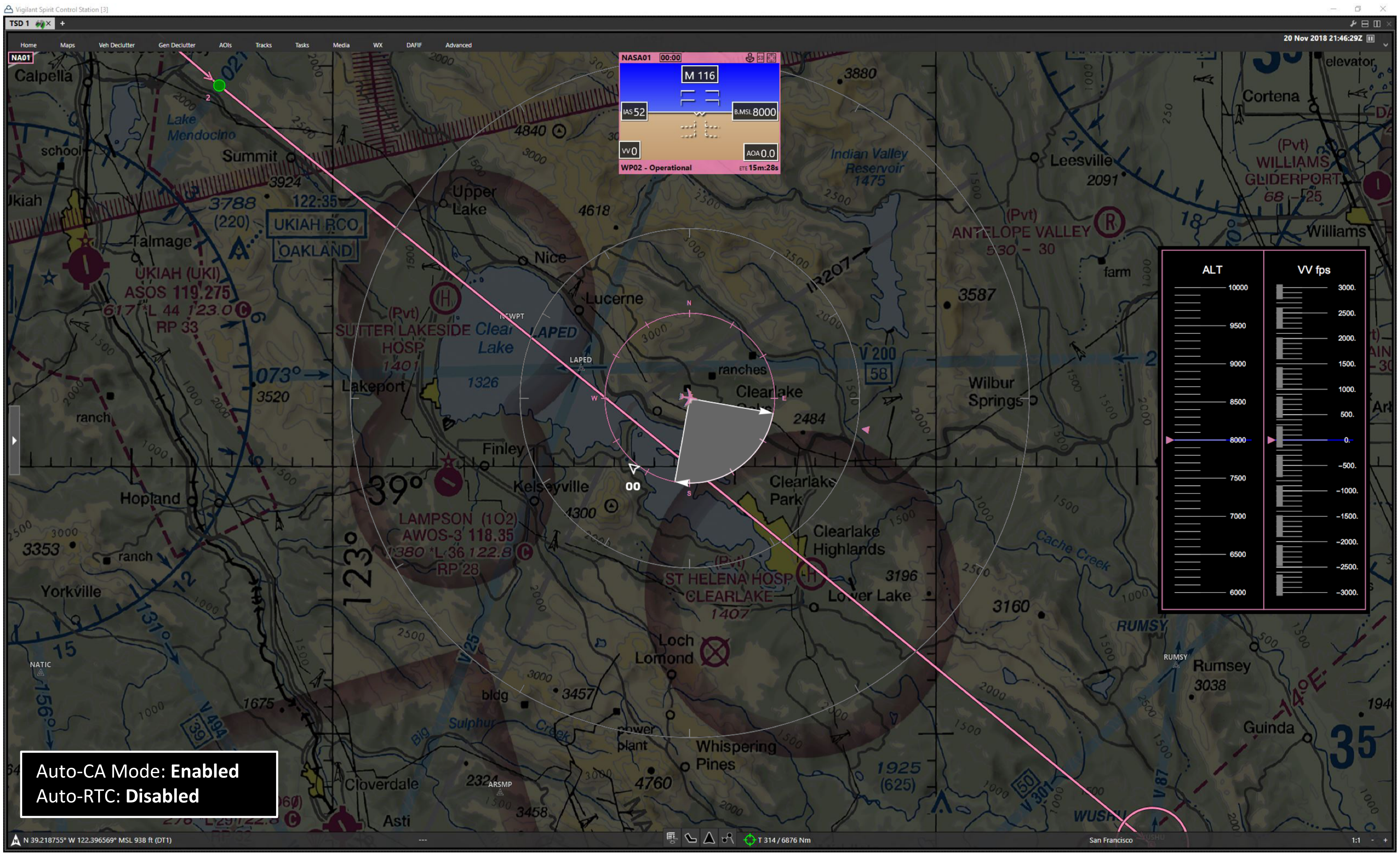
Auto CA Only – RA Issued



Auto CA Only – Clear of Conflict

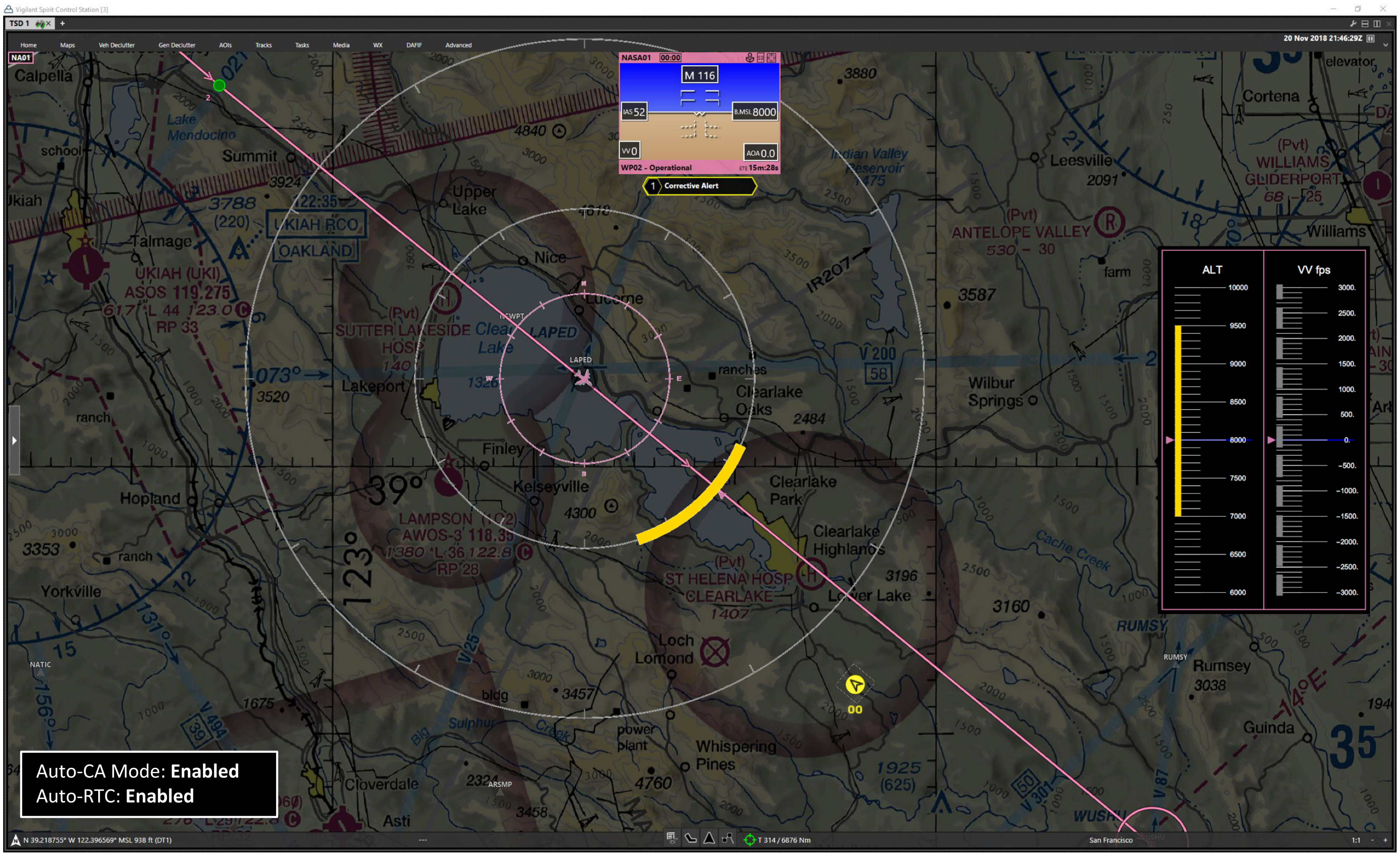


Auto CA Only – Manual RTC



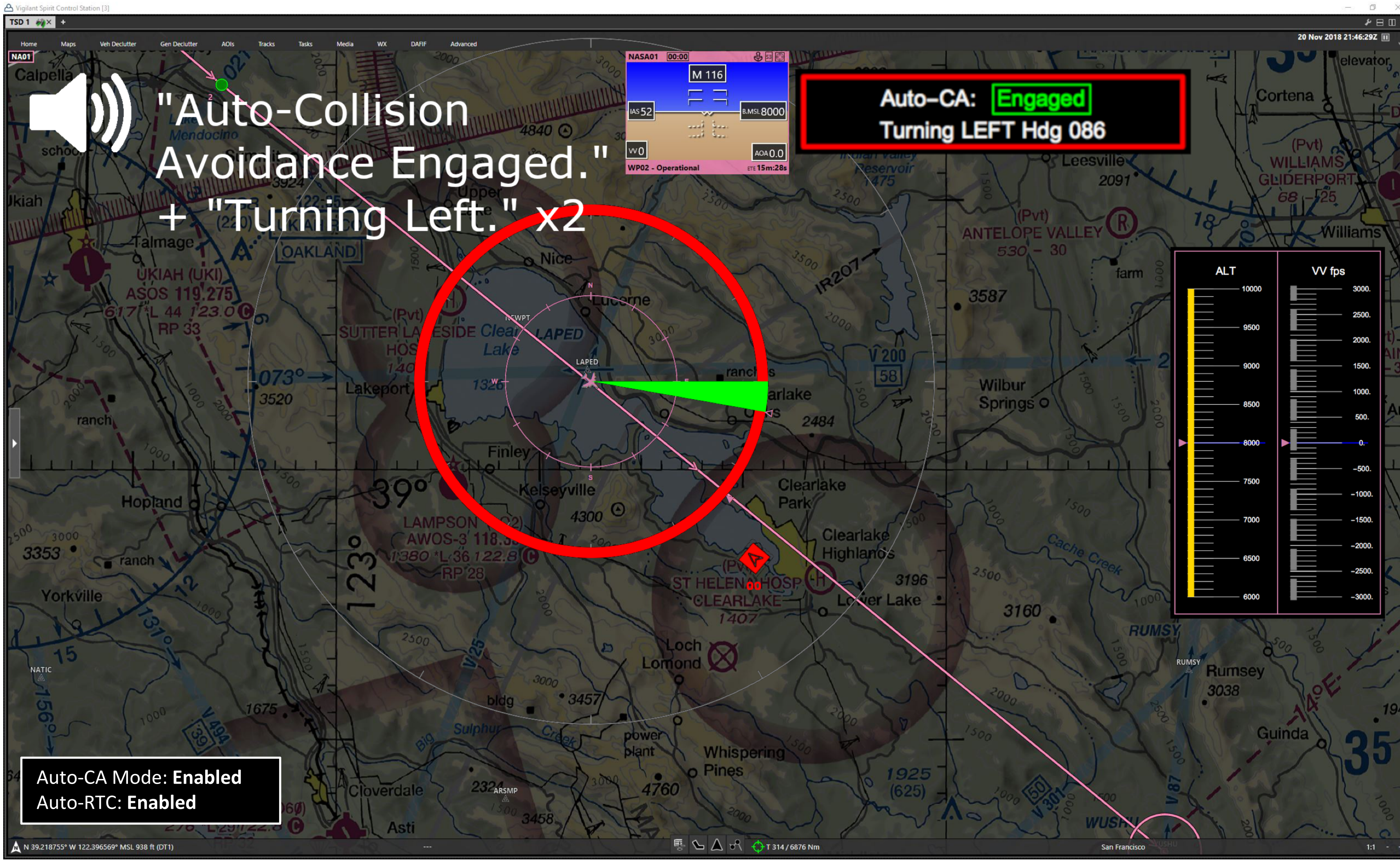
AUTO CA & RTC EXAMPLE

Auto CA & RTC – Prior to RA

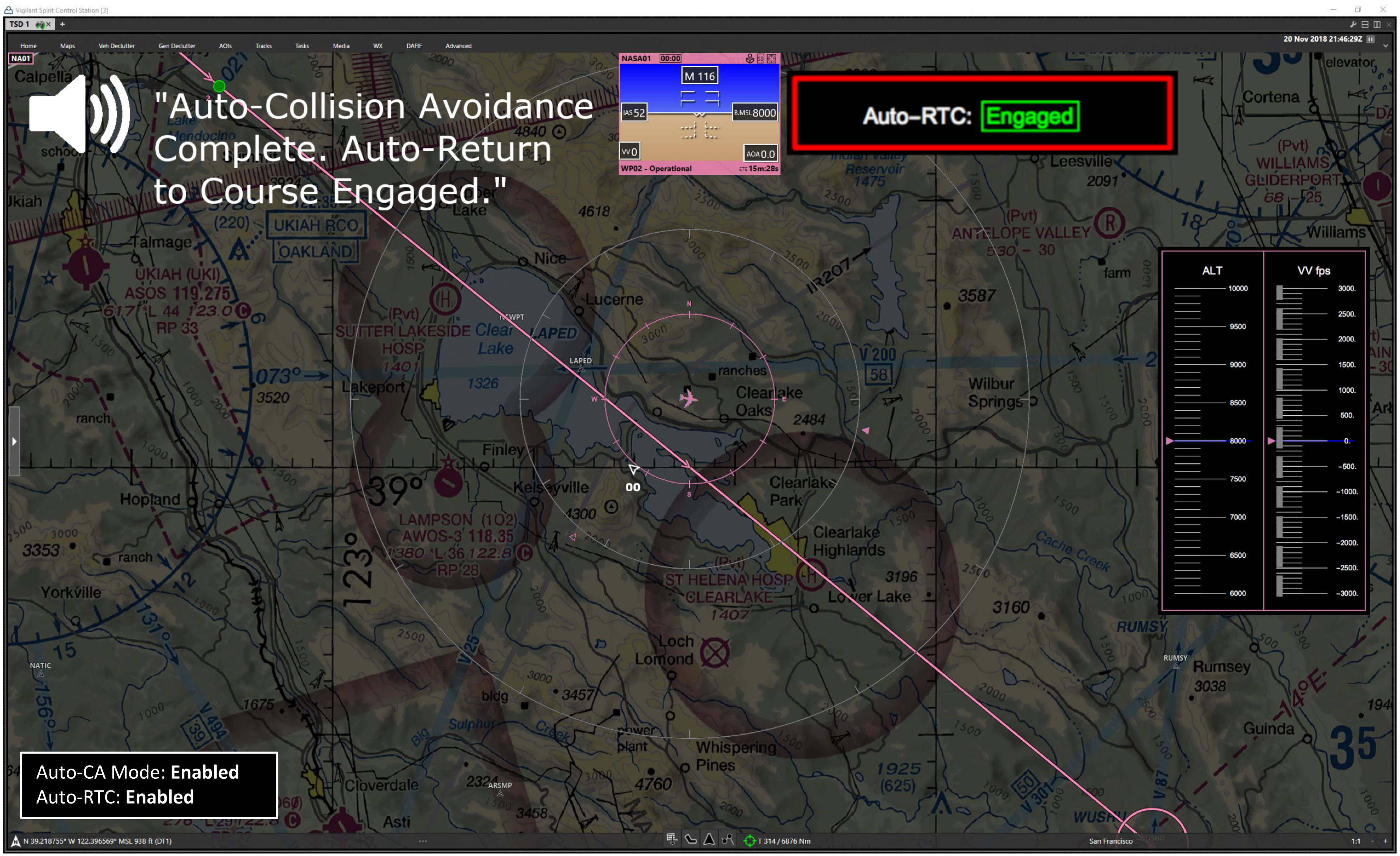


Auto-CA Mode: **Enabled**
Auto-RTC: **Enabled**

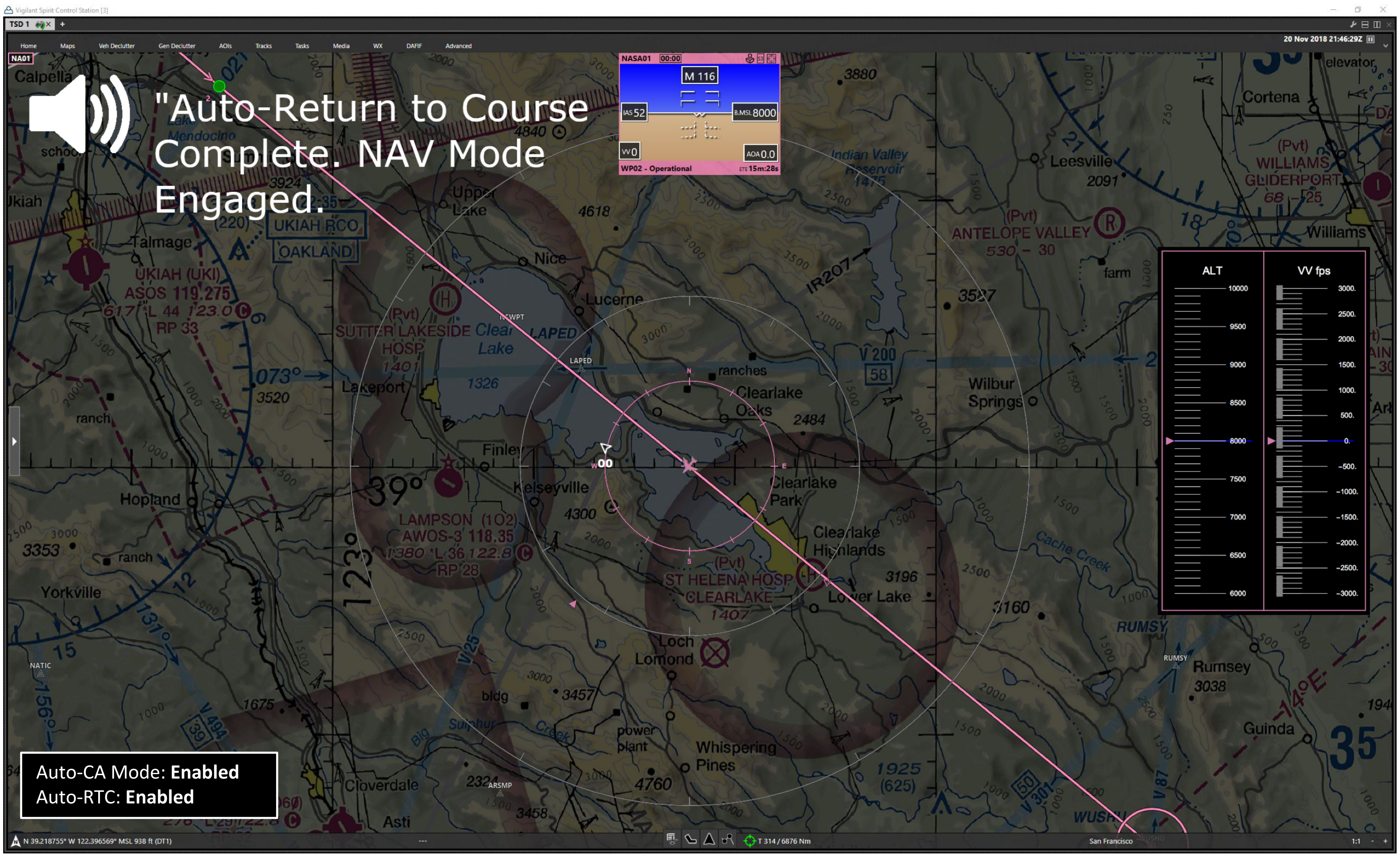
Auto CA Only – RA Issued



Auto CA & RTC – CoC & Auto RTC



Auto CA & RTC – RTC Complete



Part 2 Experimental Design

- Dependent Variables
  - Compliance rate
    - Manual condition: did the participant maneuver for traffic in accordance with the presented RA?
    - Auto CA: did the participant override the automation?
  - Reliance
    - Did the participant override the automation when it failed?
    - How long did it take the participant to override the automation?
  - Subjective ratings
    - Workload (NASA TLX)
    - Post-Trial & Post-Sim Questionnaires
    - Post-Sim Debrief (open-ended)
      - Feedback on automation implementation and areas for improvement

Part 2 Hypotheses

- Research Question
  - How does level of automation affect pilot acceptance and reliance on ACAS Xu RAs?
  - How does automation failure affect pilot response to ACAS Xu guidance?
  - Outside of cases of automation failure, when do pilots disengage auto responses?

- Expected Outcome
  - Pilots will be comfortable in allowing ACAS Xu to auto-execute CA and RTC.
  - Pilots will be relatively slow in noticing instances of automation failure.

PARTS 1 AND 2
TEST SETUP

Facilities & Resources

- Human System Integration team
- Facilities: HAT Lab, N-262 Rms. 243
- Ground Control Station
  - Vigilant Spirit Control Station
  - Custom artificial ACAS Xu RA injection tool
    - Allows researcher to specify type and timing of ”canned” RAs
    - Have coordinated with Xu team members to best approximate genuine Xu RAs
- Note: the engineering analysis does not include pseudopilots or air traffic controllers

Test Setup

Part 1

- 5 experimental participants
  - Private pilots with TCAS II experience
- Four experimental trials (45 minutes each)
  - Counter-balance two RAs of each type (e.g., horizontal-only, blended-simultaneous) and two non-RA intruders
- Pilot task: comply with RAs

Part 2

- 5 experimental participants
  - UAS active duty
- Three experimental trials (45 minutes each)
  - Counter-balance two RAs of each type (e.g., horizontal-only, blended-simultaneous) and two non-RA intruders
- Pilot task: comply with RAs and manage automation

Ownship configuration (Part 1 and 2)

- Generic MQ-9 model
- Cruise speed: 110 KTAS
- Climb/descent rate: 1,000 fpm

Schedule

- ✓ Experimental Design: NOV 2018 – JAN 2019
- ✓ Initial Software Installation + Tests: NOV 2018 – FEB 2019
- ✓ Scenario Design: NOV 2018 – JAN 2019
- ✓ Programming: NOV 2018 – FEB 2019
- ➢ Recruitment: DEC 2018 – FEB 2019
- ➢ Shakedown Tests: MAR 4, 2019 – MAR 8, 2019
- ❑ Data Collection:
  - MAR 11 – 15, 2019 (Part 1, 5 participants)
  - MAR 25 – 29, 2019 (Part 2, 5 participants)
- ❑ Data Analysis: MAR 18, 2019 – APR 19, 2019
- ❑ Data Reporting: MAY 2019

Planned Products

- Experiment Reports
  - UAS-NAS Project Outbrief
  - SC-228/147 Brief
  - Conference Proceedings Paper

- Apply lessons learned to future efforts
  - Will implement display concepts refined in this mini-HITL in ACAS Xu Full Mission HITL
  - Will directly inform automation and display, alerting, and guidance requirements for SC-288.

Questions?

garrett.g.sadler@nasa.gov