THE INSTRUMENT RATING AS A SUBJECT

What It Is, How It Is Taught, and What Mastery Looks Like

Applied Pedagogy Research Lab

Guido Bartolucci, Principal Investigator

guido@appliedpedagogy.com

lab.appliedpedagogy.com

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Research conducted by AI agents (Claude, Anthropic) under human direction.
See lab.appliedpedagogy.com for methodology and verification framework.

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EXECUTIVE SUMMARY

One page. For the reader who will not read the rest.

What the Instrument Rating is. A rating — not a certificate — added to a pilot certificate that authorizes flight under Instrument Flight Rules in instrument meteorological conditions. In the U.S. the governing regulator is the FAA; the prerequisites and testing standards are encoded in 14 CFR 61.65 and the Instrument Rating — Airplane Airman Certification Standards (FAA-S-ACS-8C, current edition; ACS-8C supersedes 8B). The candidate must hold at least a Private Pilot Certificate, have logged at least 50 hours of cross-country PIC time (of which at least 10 must be in airplanes for an airplane IR), 40 hours of actual or simulated instrument time (with 15 of those received as instrument training from a CFII), one long IFR cross- country of at least 250 NM with three different approaches, pass the FAA Instrument Rating — Airplane Knowledge Test, and pass the Practical Test administered by a Designated Pilot Examiner against the ACS. The knowledge base is narrower than the Private Pilot syllabus but deeper; the skill base is dominated by a single high-stakes psychomotor-cognitive task — the instrument scan plus procedural compliance plus single-pilot resource management; the judgment base is dominated by go/no-go and continuation-bias decision making under conditions where the pilot's own senses become unreliable.

The structural fact the field cannot stop talking about. The Instrument Rating is the canonical instance of the tested-versus-working competence gap SUBJ-003 surfaced as the most consequential structural feature of regulated competences. The ACS specifies what a candidate must demonstrate on one day, in generally benign or simulated conditions, against a DPE. The working IR pilot must handle convective avoidance, icing, fatigue, autopilot failures, partial- panel scenarios, and real ATC in actual IMC with no DPE in the right seat. The field has named this gap in its own vocabulary — the "160-hour wonder," the "checkride-day pilot," "what they don't teach you in IFR training," the practitioner maxim "the rating is a license to learn IFR, not a certificate of IFR competence." The gap is real, is the subject's most important pedagogical fact, and is sharper for the IR than for the Private Pilot Certificate because the consequences of working-competence failure are more immediate and more lethal.

Current consensus on how to teach it is contested in useful ways. The FAA pushed scenario-based training (FITS) into IR pedagogy alongside Private Pilot pedagogy two decades ago; the IR-specific evidence base is even thinner than the primary-training evidence base SUBJ-003 surveyed. Part 141 schools run structured syllabi with a 35-hour minimum (versus 40 for Part 61). The largest live pedagogical disputes are: round-gauge versus glass primary training of the scan; hand-flying first versus autopilot-first; full-motion simulator versus AATD versus aircraft-only training; the role of type-specific recurrent programs (Cirrus CSIP, Bonanza Pilot Proficiency Program, Mooney M20 club programs) as substitutes for and supplements to FAA IPC currency; the appropriate response to the "160-hour wonder" gap. The empirical base for resolving these disputes is largely practitioner consensus and accident- data forensics; randomized comparative outcome studies of IR pedagogical approaches are essentially nonexistent. The lab's W2-004 finding on expertise- adaptive scaffolding maps cleanly onto the IR maneuvers-to-scenarios progression; the lab's W2-009 psychological-safety finding maps onto the CFII– student relationship; the lab's W2-010 training-pays- for-failure framework applies in a partial form because the Part 61 IR student largely pays for their own failures.

Tools dominate working IR practice and are changing fast. The IR is more tool-dependent than primary training. Avionics generations matter: a Garmin GTN 750Xi cockpit is a fundamentally different operational environment from a Garmin GNS 430W cockpit from a Cirrus Perspective+ cockpit from a steam-gauge 172 with a single VOR head. ForeFlight and Garmin Pilot have replaced paper plates and the IFR enroute paper chart workflow for most U.S. IR pilots since approximately 2014. WAAS-LPV approaches now blanket the country and have substantially displaced ILS as the operational precision approach at non-hub airports. ADS-B FIS-B in-cockpit weather has reshaped en-route weather decisions. Consumer simulators (Microsoft Flight Simulator, X-Plane) plus VATSIM ATC have become substantially more useful as IR procedure-rehearsal tools in the post-2020 era. The working IR pilot is fluent across the full stack; the checkride-day IR pilot may have demonstrated fluency only in the airframe and avionics suite used for training.

What success looks like — at the checkride. A successful IR candidate demonstrates the ACS Areas of Operation across the task list — preflight; air traffic control clearances; flight by reference to instruments; navigation systems; instrument approach procedures (precision and non-precision); emergency operations including partial panel and loss of communications; and postflight procedures. They can fly a precision approach (ILS or LPV) and at least one type of non- precision approach (LNAV, LP, VOR, or LOC) within ACS tolerances; hold; execute a missed approach; and demonstrate scenario-appropriate Risk Management across every task.

What success looks like — at the first 100 IFR hours. The newly-rated IR pilot has discovered that real IMC is more workload-saturating than the hood; that autopilot mode confusion produces silent unexpected airplane behavior at the worst times; that ATC clearances in busy airspace come faster than training prepared them for; that fatigue and dehydration degrade their scan faster than they expected; that their precise approach minimums tolerance collapses under workload. They are alive because they have flown conservatively, refused marginal weather, declared problems early, or been lucky.

What success looks like — at 500 IFR hours. The working IR pilot has internalized the upper-layer competences the ACS underweights — calibrated go/no-go judgment that catches the convective-cell development twelve hours before the takeoff; honest currency self-assessment that disqualifies them from a weather-marginal trip after a long layoff; the automaticity of the scan that lets them divert attention to a non-routine ATC instruction without the airplane wandering; the willingness to declare an emergency early; the willingness to say "unable" to a clearance they cannot safely accept. They have built what training did not give them, mostly on their own initiative or through type-club recurrent training.

The single most important learner action. *Treat the Instrument Rating as the beginning, not the end, of IFR competence formation.* The rating authorizes the pilot to fly IFR; the working competence comes from the deliberate accumulation of recurrent training, type-specific simulator exposure, actual-IMC under appropriate supervision, and consequential decisions made and reviewed. The recurrent-training apparatus (IPC under 14 CFR 61.57(d); type-specific CSIP and PPP programs; the Pilot Workshops IFR Mastery continuing-education tradition; AOPA Air Safety Institute IR-specific case studies) exists precisely because the rating is not the competence target.

The single most important non-recurring decision. The choice of *what to fly IFR in*. The light-single non-FIKI airframe (Cessna 172, Cherokee, DA40, SR20) has a real IFR operating envelope that excludes most known icing and most embedded convection. The high-performance non-FIKI airframe (SR22 normally- aspirated, Bonanza, Mooney M20J) extends the envelope modestly but not into icing. The FIKI-certified airframe (SR22T with FIKI, Cirrus Vision Jet, TBM, Pilatus PC-12) extends the envelope into known icing. For the GA pilot, this choice — far more than the choice of CFII or ground school — determines what the IR is actually worth on the days the pilot intends to use it.

Recommended free resources. *Instrument Flying Handbook* (FAA-H-8083-15B, current as of January 2026) for the knowledge spine; *Instrument Procedures Handbook* (FAA-H-8083-16B, 2017) for the ATC-side procedural spine; *Aviation Weather Handbook* (FAA-H-8083-28B, April 2026) for weather; the current *Instrument Rating Airplane ACS* (FAA-S-ACS-8C) for the checkride spec; AIM Chapter 5 for current ATC procedures; 14 CFR Part 91 Subpart B for the IFR operating rules; AOPA Air Safety Institute IFR- specific case-study courses for judgment development. All FAA handbooks are free PDFs on faa.gov. Two non- free books that every IR pilot should own: Bob Buck's *Weather Flying* and Richard Collins' *Flying IFR* (both regularly reprinted; the former in particular is unmatched for IFR-pilot weather sense).

The lifetime cheat sheet for the rated IR pilot is at `cheat-sheet.md`. **The PI-specific single-pilot GA-IFR curriculum** is at `pi-ir-curriculum.md`. This review is the audience-agnostic subject investigation that anchors both.

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PART I — WHAT COUNTS AS THE INSTRUMENT RATING

The Instrument Rating, like the Private Pilot Certificate it builds on, is a regulated competence, which means its borders are unusually crisp in some respects and unusually contested in others. The FAA defines the rating operationally — through a prerequisite list, a knowledge test, and a practical test — and the IR-tested competence is again a strict subset of the working IR-pilot competence. For the IR the gap between the two is even larger than for the Private Pilot Certificate, and the gap drives the rest of this review.

2.1 THE REGULATED DEFINITION

The Instrument Rating — Airplane is defined by 14 CFR 61.65 (Instrument rating requirements), tested against the Instrument Rating — Airplane Airman Certification Standards (FAA-S-ACS-8C, the current edition that superseded FAA-S-ACS-8B), and exercised under the operating rules in 14 CFR Part 91 Subpart B. Specifically, the rating authorizes flight under Instrument Flight Rules in instrument meteorological conditions in airplanes for which the pilot holds the appropriate category and class rating. The rating is *added* to the existing certificate; it is not itself a certificate. A pilot holding a Private Pilot Certificate — Airplane Single-Engine Land with an instrument rating may file and fly IFR in any single- engine airplane for which they meet 14 CFR 61.57(c) recent-experience requirements.

This has three immediate pedagogical consequences. First, the IR is a **narrow, deep** add-on rather than a broad, shallow one. The Private Pilot syllabus covers ten broad areas (regulations, aerodynamics, systems, performance, weather, airspace, navigation, communications, maneuvers, ADM); the IR syllabus deepens four of those (regulations specific to IFR operations; weather specific to IMC; navigation specific to the instrument approach system; ATC communications specific to the IFR clearance system) and adds two new ones (basic-attitude instrument flight, full and partial panel; instrument approach procedures including holding and the missed-approach). Second, the **assessment apparatus is identical in structure** to the Private Pilot apparatus — knowledge test plus practical test, both ACS-shaped — but the content is concentrated on the new and deepened material. Third, the **tested-versus-working gap** is even more consequential, because the ACS can only evaluate one day's performance in conditions the DPE considers safe to evaluate in. The working IR pilot must handle the conditions the DPE would not evaluate in. That gap, for the IR, includes the substantial fraction of the year-round IFR operating envelope where icing, embedded convection, and night low- visibility IMC occur.

The lab's framework on regulated competence applies here in extended form. SUBJ-003 §I established the regulated-competence pattern; the IR sharpens it. The W2-010 training-pays-for-failure inversion is in partial operation here: the FAA does pay a social cost for IR-pilot failures (loss of life, NTSB and Congressional attention, regulatory pressure on the training apparatus), and the regulatory floor exists because of that. But the *learner* still bears most of the direct cost — the checkride fee, the training hours, the cost of an aborted training program, and, crucially, the cost of accidents the rating did not prevent. The CFII's incentives are partially aligned with the student's outcomes but include hour-building considerations the chief CFI and DPE oversight

only partially constrain. The result is a regulated- competence regime that produces a credentialed floor but does not produce a working ceiling on its own.

2.2 THE THREE TIERS — CORE, STANDARD, PERIPHERAL

Below is the taxonomy used as the organizing spine of the rest of this review. The tier structure parallels SUBJ-003's but the content reflects the IR's narrower and deeper scope.

Core — the ACS-tested Instrument Rating body. The material every candidate must demonstrate to earn the IR. The ACS specifies the Areas of Operation; the reference handbooks (IFH, IPH, AIM Chapter 5, 14 CFR Part 91 Subpart B, Aviation Weather Handbook, and the applicable POH/AFM) define the substantive content. The core comprises seven broad areas:

1. *IFR regulations* — 14 CFR Part 61 Subpart B (the instrument rating prerequisites); 14 CFR 61.57(c) and (d) for currency and the IPC; 14 CFR Part 91 Subpart B in full, with particular attention to 91.167 (alternate fuel), 91.169 (IFR flight plan and alternate-required criteria — the "1-2-3 rule"), 91.171 (VOR equipment check), 91.173 (ATC clearance required), 91.175 (takeoff and landing under IFR, including approach minimums), 91.177 (minimum altitudes), 91.183 (IFR communications and required reports), and 91.185 (IFR lost- communications procedures). 2. *IFR-relevant weather* — instrument meteorological conditions; the cloud-and-precipitation regime in which IMC develops; icing meteorology and the icing-pilot decision regime; convective weather identification, avoidance, and the embedded- thunderstorm problem; fog and visibility minima; the FAA aviation weather product suite specific to IFR planning (the GFA replacement for the FA; AIRMET Zulu, Tango, and Sierra; SIGMETs and Convective SIGMETs; the Center Weather Advisory; the alternate weather minima specified in 91.169 and the FAA-published "1-2-3 alternate" criteria). 3. *Basic attitude instrument flight (BAIF)* — the instrument scan, in full panel and partial panel, including straight-and-level, climbs, descents, and turns to specified headings and altitudes; the recovery from unusual attitudes by reference to instruments; the discipline of trim, power, and pitch attitude control with no outside reference. 4. *Navigation under IFR* — VOR/DME navigation; GPS/RNAV navigation including LNAV, LP, LNAV+V, LNAV/VNAV, and LPV minima; the Performance-Based Navigation framework as it applies to the GA IR pilot; the en-route environment and the IFR enroute chart; the airway system and the off-airway direct-route system; minimum altitudes for IFR operations (MEA, MOCA, MIA, OROCA, MVA, MCA). 5. *Instrument approach procedures* — the approach plate as a literacy system (plate symbology, profile view, plan view, briefing strip, missed- approach text); the precision approach (ILS and LPV); the non-precision approach (LNAV, LP, VOR, LOC); the circling approach; the timed approach; the procedure turn and the racetrack; the teardrop and parallel and direct entries to a holding pattern; the missed-approach procedure; the alternate-airport requirements. 6. *ATC communications under IFR* — clearance copy and readback; the standard IFR clearance format (Clearance Limit, Route, Altitude, Frequency, Transponder — CRAFT); position reports under 91.183; required reports including unable-to-climb and missed-approach; the lost-communications procedure under 91.185; pilot/controller roles under AIM 5-5. 7. *Single-pilot IFR resource management* — the single-pilot variant of CRM (SRM); workload management; the scan-plus-procedure-plus-comms integration; autopilot mode awareness and the discipline of disconnecting when uncertain; recognition of partial-panel and failed-instrument scenarios; the cockpit-resource hierarchy of automation levels (full coupled, flight director only, hand-flown); the briefing discipline before each phase of flight.

Add to this the **Risk Management Elements** the ACS makes part of every task (the IR ACS, like the PPL ACS, has the Knowledge / Risk Management / Skill triplet at every task), and the **specific endorsements** that travel with the rating but are not the rating itself (the CFII signoff for

satisfactory ground training; the CFII signoff for satisfactory flight training; the recent-experience endorsements under 61.57(c) and (d); the IPC endorsement under 61.57(d)).

A learner with all of this can pass the IR ACS practical test. The mandate calls this the IR-tested body. The lab's competence-stack vocabulary maps it to Layers 1 and 2 with formal Layer 3 instrumentation in the Risk Management Element. Layers 4 and 5 are present in the ACS language but, as for the PPL, cannot be tested in their full sense by a one-day evaluation.

Standard advanced — what working IR pilots routinely acquire beyond the rating. Material that almost every active IR pilot picks up in the first few hundred post-rating IFR hours but that is not formally part of the IR practical test. This includes:

- *Type-specific autopilot fluency* — the Garmin GFC 500, the S-TEC 55X or 3100, the Cirrus Perspective+ DFC (Garmin GFC 700 with Cirrus configuration), the Avidyne DFC 100, or the legacy Bendix/King KFC 200 series; the modes available, the mode-confusion failure modes, the coupled-approach behavior, the level (blue-button) mode where present, the disconnect-and-hand-fly discipline. - *Type-specific avionics fluency* — the GTN 650/750/Xi series; the GNS 430W/530W legacy series; the Avidyne IFD 440/540/550 family; the Cirrus Perspective+ MFD/PFD; the G1000 NXi; the G3X Touch; the Aspen Avionics PFD; the standalone Garmin G5/G500. For each, the IFR-flow procedure for: loading and activating an approach; setting up a hold; managing an approach amendment; using the flight planner; integrating the autopilot. - *EFB IFR fluency* — ForeFlight or Garmin Pilot or FltPlan Go used at the working-pilot level; the briefing pack for an IFR trip; the procedure advisor (where present); the in-flight weather integration; the approach-plate organization on the iPad. - *Real-IMC weather sense* — Bob Buck-style "weather flying" judgment built up over years of actual exposure; the recognition of which forecasts to trust; the pattern recognition of frontal-passage timing; the convective-cell development tracking; the icing-layer-mapping discipline. - *ATC fluency under workload* — fast clearances in busy IFR airspace; the en-route handoff cadence; the approach control vector and altitude assignments; the standard amendment phrases; the discipline of "unable" when an instruction cannot be safely complied with. - *Currency-honest IPC discipline* — the difference between legal 6/6/HIT currency under 61.57(c) and actual flying-in-IMC competence; the type-specific recurrent training cadence; the every-six-months IPC-equivalent practice with a CFII. - *Recurrent emergency-procedure practice* — partial panel; autopilot failure on approach; loss of communications on the approach; engine roughness in IMC; fuel-system problems in IMC; the rapid decision-tree for "land here now" versus "divert" versus "continue." - *Single-pilot CRM* — the workload-triage discipline; the briefing-confirm-execute workflow; the cockpit-flow rhythm; the discipline of programming changes only when the airplane is in a stable configuration.

This tier is what the practitioner literature calls "the working IR pilot competence" and what the "160-hour wonder" critique points at. It is not optional in any practical sense; the pilot who does not acquire it is the pilot the accident data identifies as a hazard. The body of this material is the locus of the IR-specific tested-versus-working gap that drives the rest of this review.

Peripheral or contested — included in some curricula, excluded from others. Material that some IR pilots acquire as defining parts of their practice and other IR pilots never touch. This includes:

- *Stormscope / Strikefinder interpretation* — the ground-based-lightning-receiver class of in-cockpit weather, declining in market share as ADS-B FIS-B has matured but still installed in many older airframes and still useful in radar-shadow conditions. - *Airborne weather radar interpretation* — the on- board weather radar found in high-performance singles and twins; the tilt management; the attenuation problem; the discipline of "what radar does not show is more dangerous than what it shows." - *FIKI flying* — the operation of Flight Into Known Icing-certified airframes (SR22T with FIKI, Vision Jet, TBM, PC-12); the inadvertent-icing-encounter procedures in non-FIKI airframes;

the equipment airworthiness regime under 14 CFR 91.527. - *High-altitude IFR* — operations above FL180; the RVSM regime above FL290; the oxygen requirements; the pressurization-system competence; the high- altitude weather environment (jet stream, clear- air turbulence, hypoxia). - *Oceanic and remote-area IFR* — the international operations regime; the position-report cadence without radar coverage; ETOPS-relevant procedures. - *Single-pilot turbine IFR* — the operational differences between piston-IFR and turbine-IFR flying; the type-specific simulator-based recurrent training programs (FlightSafety, CAE/SimCom). - *Formal CRM coursework* — the airline-CRM tradition as it filters down to GA single-pilot operations; the FAA WINGS CRM modules; the AOPA Air Safety Institute "Single Pilot Resource Management" course. - *Specific glass-cockpit reversion and partial-panel doctrine* — the Garmin G1000 reversion procedure; the Avidyne backup-attitude procedure; the Perspective+ Backup Standby Display use; the cross-airframe consistency or inconsistency of reversion-mode behavior. - *The Performance-Based Navigation doctrine in full ICAO expression* — the RNP 0.3 and RNP AR approaches; the LPV-200 and LP/V approach taxonomies; the FAA's NextGen suite and its GA-relevant subset. - *International IR rating reciprocity* — the conversion of an FAA IR to an EASA IR or vice versa; the ICAO IR equivalent operations under foreign registration.

This tier varies more by airframe, mission profile, and practitioner community than by formal curriculum. A pilot's identity as an IFR flyer is shaped here more than in the core tier; the core tier is the floor, the peripheral tier is the texture.

2.3 THE BORDERS WITH ADJACENT SUBJECTS

The IR sits next to several subjects with which it shares material but from which it is distinct. The borders matter because a learner asking "what should I study?" is implicitly asking "as opposed to what?"

- **Aviation weather.** Aviation weather (proposed SUBJ-006 candidate in SUBJ-003 dispatch §I) is its own subject. Some weather knowledge is core IR content (icing meteorology, convective avoidance, the IFR product suite); some weather knowledge is meteorology-as-a-subject (synoptic-scale dynamics, satellite-imagery interpretation past the FAA product level, the mesoscale models). The IR curriculum includes the working-pilot subset; deeper weather competence is its own pursuit. - **Aerodynamics of instrument flight.** The aerodynamics of stall, spin, and unusual-attitude recovery overlap SUBJ-003 Part II; the IR-specific content is the *recognition-by-instrument-reference* rather than the underlying aerodynamics, which are unchanged from VFR flight. The aerodynamics of icing accretion and its handling-quality effects are unique to instrument flight in the practical sense — they don't matter VFR because you avoid the conditions; they matter IFR because you may not see them coming. - **Aviation decision-making and SRM.** ADM, TEM, and SRM are their own subject (proposed SUBJ-007 candidate). The IR curriculum exercises judgment through the named ADM frameworks (PAVE, IMSAFE, 3P, 5P) and the explicit go/no-go-for-IFR vocabulary, but the underlying ADM body of knowledge is broader than the IR-specific application. - **ATC procedures and airspace.** The IFR-specific ATC and airspace knowledge is core IR content; the broader ATC operational doctrine (FAA Order JO 7110.65; the controller's vocabulary; the radar-separation rules) is on the controller side and shades into knowledge pilots need only partially. - **Type-rating training (turbine, jet, multi- engine).** Multi-engine instrument and turbine- type IR training are separate pursuits and are not the FAA Instrument Rating — Airplane (Single-Engine Land) this review addresses. - **The CFII track (proposed SUBJ-005 candidate per SUBJ-003 dispatch §I).** The CFII is the teaching credential built on the IR; it is its own subject with its own pedagogy curriculum, requiring the IR as prerequisite.

2.4 THE BORDERS WITH THE NON-CERTIFICATED IFR COMMUNITY

Three practitioner communities adjacent to the certificated-IR-pilot world deserve note because they shape training norms.

- **The "IFR-for-safety" VFR pilot.** The pilot who has done substantial Stage 1–4 work in the five-stage progression SUBJ-003's ifr-for-safety- guide laid out, but who has not sat the IR practical test. Operationally adjacent to the rated IR pilot but legally unable to file IFR or fly in IMC; pedagogically a sometimes-better- prepared pilot than a "checkride-day" IR pilot, because the IFR-for-safety pilot has built capability without the regulatory pressure of the checkride deadline. The PI's IFR-for-safety-guide in SUBJ-003 lays out this trajectory explicitly. - **The simulator-only IFR pilot.** The VATSIM and PilotEdge community has produced a substantial cohort of skilled procedural pilots who have filed and flown hundreds of IFR cross-countries in simulation, learned approach plates fluently, and developed ATC fluency that often exceeds working GA IR pilots' — without ever flying an actual approach in actual IMC. The boundary between this community and certificated IR aviation is increasingly porous; some primary IR training is now augmented with PilotEdge time as ATC-fluency rehearsal. - **The lapsed-IR pilot.** The largest single category in the rated-IR-pilot population, by some practitioner estimates: pilots who hold the rating but are not 61.57(c)-current, who fly VFR-only, and who would need an IPC before re-engaging IFR operations. Operationally this is a distinct community from the active-IR-pilot community; the recurrent-training apparatus is partially designed to address the re-engagement problem.

2.5 THE TESTED-VERSUS-WORKING COMPETENCE GAP

Now to the structural argument the rest of this review takes as given. For the IR the gap between the ACS- tested competence and the working-IR-pilot competence is *larger* than the equivalent gap for the Private Pilot Certificate and is the most important pedagogical fact about this subject.

The **IR-tested body** is what the ACS evaluates on the practical test. It is by design observable, scoreable, and single-encounter. The DPE schedules the test for a day with usable weather (the FAA Inspector's Handbook expects the DPE not to schedule a test in conditions the DPE considers unsafe to fly in; the DPE bears liability for the conduct of the test). The candidate flies the test under simulated IMC (foggles or a hood) or, in some cases, in actual benign-IMC IFR. The maneuvers, holding, approaches, and missed-approach are flown to ACS tolerances. The Risk Management Element of every task is exercised through scenario questioning. The candidate demonstrates partial-panel competence by recovering from an instructor-induced failure of the attitude indicator or the heading indicator. The candidate demonstrates clearance copy, position reports, and lost-comm awareness through scenario or actual practice. The candidate either passes or fails based on observable performance against the ACS standard.

The **working-IR-pilot body** includes the tested body and adds at least the following:

- *Calibrated weather judgment over years.* The certificate-day evaluation is in benign IMC at worst; the career-day weather is contingent. The IR pilot must develop a personal-minimums calibration that the certificate did not require them to demonstrate, plus the working knowledge of which seasonal weather patterns to fly in and which to scrub. The seasonal IFR-flying envelope is much narrower than the regulatory envelope; a competent IR pilot in the Midwest does not file IFR through a Convective SIGMET, even though nothing in the regs forbids it. - *Icing-encounter decision tree.* Most IR pilots fly non-FIKI airframes. The recognition of inadvertent icing onset (the leading-edge ice accretion; the abnormal climb-rate decay; the unanticipated trim change), the immediate-action response (descent into warmer air; climb above freezing layer; turn out of

the cloud layer if the airframe still can; declare and request vectors), and the do-not-extend-flaps discipline — none of this is testable on the checkride day because the DPE will not schedule in known icing. - *Convective avoidance during the flight.* The pilot-discretion call to deviate around a building cell that ATC is not yet vectoring around; the reading of the in-cockpit NEXRAD with its 5–15- minute latency; the discipline of treating cell development as direction-and-rate, not as fixed position; the willingness to refuse a vector that takes the airplane into a cell. - *Autopilot management under real workload.* The ability to recognize when the autopilot has captured the wrong mode, the wrong altitude, or the wrong course; the discipline of disconnecting *first* and diagnosing *second*; the hand-fly competence the autopilot dependency erodes. - *ATC fluency under workload.* The clearance amendment in busy airspace, taken correctly the first time without a "say again"; the position report at the correct fix; the discipline of "unable" when the assigned altitude is in icing or when the assigned routing takes the airplane through a cell. - *Approach-plate fluency under workload.* The ability to brief a new plate, set up the avionics, and confirm the missed-approach in the minute before commencing the approach — without the airplane wandering or the pilot losing the picture. - *Currency-honest self-assessment.* The 6/6/HIT rule under 61.57(c) is a legal floor that bears little relationship to working competence. A pilot who has flown six approaches in a sim in the last six months is legally current; a pilot who has flown six actual-IMC approaches in unfamiliar airframes is differently and more meaningfully current. The discipline of saying this out loud is what separates the working IR pilot from the legally-current one. The IPC every six months, with a CFII who actually challenges the pilot, is the partial remediation. - *Single-pilot CRM and workload triage.* The discipline of A-N-C-M (aviate, navigate, communicate, *manage* the avionics) and the discipline of dropping the lowest-priority task when workload spikes. The recognition of task-saturation building before it tips over. - *Willingness to declare an emergency, refuse a clearance, or divert.* The Layer-5 character dispositions that the checkride cannot test directly. The willingness to bear the social and financial cost of "we land here now instead of continuing to the destination wedding."

The field has named most of these in its own vocabulary — IFR "weather sense," "single-pilot discipline," "airmanship under IFR," "the good IR pilot." The lab's competence-target vocabulary offers a cleaner taxonomy than the field's overlapping practitioner language, but the field's vocabulary is what working IR pilots actually use, and this review will use it alongside the lab's stack notation.

The honest summary: a freshly-rated IR pilot has the floor. A working IR pilot at 500 IFR hours, with deliberate recurrent training, type-specific simulator exposure, and supervised actual-IMC exposure, has built the rest. The rating is the beginning, not the end. The review's organization takes this as given.

2.6 THE SEVERITY OF THE GAP

The IR tested-versus-working gap is more consequential than the PPL equivalent for three structural reasons.

First, the **failure modes are more lethal**. A VFR pilot who exceeds their personal minimums has degrees of recovery available — divert, land at the nearest airport, descend below the layer in clear air. An IR pilot who exceeds their personal minimums in actual IMC is in a more compressed decision space — they may not be able to descend below the layer; they may be in icing; they may be inside an embedded cell; they may have only minutes to make a decision the checkride day did not equip them for.

Second, the **diagnostic feedback is sparser**. A VFR pilot accumulates working-competence cues every flight — the wind feels different than forecast; the crosswind landing felt sloppy; the engine

sounded rougher than usual. An IR pilot who flies six actual- IMC approaches in twelve months has six opportunities to discover that their approach-brief discipline is slipping, that their scan breaks down under workload, that they are slow on autopilot mode changes. The working-competence feedback loop is too sparse to self-calibrate without explicit recurrent training.

Third, the **technology gradient is steeper**. The working IR cockpit in 2026 is substantially more complex than the working VFR cockpit. The autopilot mode logic of a Garmin GFC 700 in a Cirrus Perspective+, with VNAV and coupled approach capability, has more failure modes than the manual flight of a VFR-equipped 172. The avionics setup required to fly an LPV approach is more elaborate than the setup required to fly a VFR cross-country. The fluency required to manage the avionics under workload is more skill, not less, than the VFR equivalent. The certificate-day exam evaluates the configured fluency; the working-day flight evaluates the under-stress fluency. The gap is what the "automation surprise" literature (Sarter & Woods, 1995; Sarter, Woods & Billings, 1997) has named in the airline context and what the FAA's AC 90-109A has codified for the GA TAA transition context.

The lab's competence-target framework applies directly. The IR-tested body addresses Layers 1 and 2 adequately, Layer 3 formally, and Layers 4 and 5 indirectly. The IR-working body requires all five. The pedagogical apparatus for closing the gap exists — recurrent training, type-specific recurrency programs, scenario-based instruction, the AOPA Air Safety Institute IR-specific case-study libraries — but the gap closure is not built into the regulatory floor and depends on the individual pilot's willingness to invest in the recurrent work. The lab's W2-009 finding on psychological safety as a constitutive prerequisite for upper-layer competence formation applies here in muted form: the CFII– student relationship needs to be psychologically safe enough for the student to admit "I don't know what that mode just did" rather than perform competence. The lab's W2-010 finding on training-pays-for-failure applies in inverted form: the IR-pilot pays for failure (in money, in license, in life), and the training apparatus is partially designed around this — but the cost-of-failure structure is what makes the gap closable in principle.

The rest of this review treats the gap as the first- order design axis. Part II surveys the curricular apparatus through this lens. Part III surveys the pedagogical traditions through this lens. Part IV surveys the tools through this lens. Part V maps the outcomes to the competence stack with explicit attention to which outcomes the rating produces and which the rating does not. Part VI surveys the assessment apparatus and asks what would close the gap if anything could. Part VIII enumerates the specific failure modes the apparatus produces and the partial remediations the field has converged on.

3

The IR has a smaller and more uniform canonical-text set than primary training, a more diverse and more opinionated commercial-courseware market, and a school landscape that splits cleanly between Part 61 indie- CFII paths and Part 141 structured programs. Pricing runs higher than primary training on a per-hour basis because the airplane time is more demanding to provide (the CFII must be IR-current and IFR-comfortable, the airplane must be IFR-equipped, the flight must be in IFR-permissible weather or with a hood and safety pilot) and lower than the airline-pipeline programs because the rating is a discrete add-on rather than a career-track investment.

3.1 THE FAA HANDBOOK SERIES FOR THE IR

The Federal Aviation Administration's IR-specific handbooks are the authoritative reference texts. All are free PDFs on faa.gov. Current editions as of May 2026:

- **FAA-H-8083-15B, *Instrument Flying Handbook* (IFH).** Originally released 2012; includes addenda and errata through January 2026. The knowledge spine for IR training. Covers the national airspace system, ATC system, human factors, aerodynamics of instrument flight, flight instruments, IFR maneuvers, navigation systems, and emergency operations. The material applies to both round-gauge and glass-cockpit primary instrumentation. ~400 pages. - **FAA-H-8083-16B, *Instrument Procedures Handbook* (IPH).** Effective October 2017. The procedural companion to the IFH — covers IFR clearances, SIDs and ODPs, en-route operations, STARs, holding, approaches from the ATC-system side, and the procedural choreography that the IFH treats from the pilot side. ~250 pages. - **FAA-H-8083-28B, *Aviation Weather Handbook*.** April 13, 2026. The consolidated weather reference that replaces the older AC 00-6 and AC 00-45 and consolidates the convective, icing, windshear, and mountain-weather ACs. ~530 pages. For the IR pilot, Chapters 18 (Thunderstorms), 19 (Icing), and 20 (Windshear), plus the IFR-product-suite chapters, are load-bearing. - **FAA-H-8083-2A, *Risk Management Handbook*.** June 2022. The framing document for PAVE, IMSAFE, DECIDE, 3P, and 5P. The 5P (Plan, Plane, Pilot, Passengers, Programming) addition is specifically aimed at glass-cockpit IFR pilots. - **FAA-H-8083-25C, *Pilot's Handbook of Aeronautical Knowledge* (PHAK).** 2023. The general knowledge spine for the Private Pilot syllabus; chapters on aerodynamics, weather, performance, regulations, and airspace remain relevant for the IR review. - **FAA-H-8083-9B, *Aviation Instructor's Handbook*.** 2020. The pedagogy reference for the CFI/CFII pipeline; relevant to this review for the scenario-based-training (FITS) doctrine the FAA embedded in the 9B edition. - **FAA-H-8083-6, *Advanced Avionics Handbook*.** 2009, no revision letter. The handbook the IFR pilot needs for glass-cockpit fluency; the dated edition is a real gap, since the 2009 handbook predates the G1000 NXi (2017), the GTN 750Xi (2019), the Avidyne IFD550 (2014), and the Perspective+ revision (2017). The current GA glass- cockpit landscape is substantially under-served by the official FAA handbook; pilots must rely on manufacturer training material and third-party resources for the working-cockpit-specific content.

3.2 THE INSTRUMENT RATING ACS

The **Instrument Rating — Airplane Airman Certification Standards** (FAA-S-ACS-8C) is the current testing specification, having superseded FAA-S-ACS-8B. The ACS structure — Knowledge / Risk Management / Skill triplet for every task within every Area of Operation — is the same testing structure the Private Pilot ACS uses; the IR ACS Areas of Operation cover Preflight Preparation, Preflight Procedures, ATC Clearances and Procedures, Flight by Reference to Instruments, Navigation Systems, Instrument Approach Procedures, Emergency Operations, and Postflight Procedures. The Companion Guides (FAA-G-ACS-2 for pilots; FAA-G-ACS-1 for evaluators) define the DPE-conduct framework.

The Knowledge Test (the FAA IRA — Instrument Rating Airplane) is computer-delivered by PSI Services. 60 multiple-choice questions, drawn from a published question bank, 70% pass standard, 2.5-hour time limit. The Practical Test (oral followed by flight test) is administered by a Designated Pilot Examiner against the ACS. The oral runs 1–3 hours; the flight runs 1.5–2.5 hours. National first-time pass rate is high (practitioner reports cluster around 88–93% for the knowledge test; flight test pass rates vary by DPE and school). DPE fees in 2026 cluster around $800–$1,200 for the IR practical test.

3.3 THE MAJOR COMMERCIAL GROUND SCHOOLS

Five commercial vendors dominate the IR ground-school and knowledge-test prep market. The 2026 prices below are list prices, not bundled deals.

- **King Schools — Instrument Rating Ground School & Test Prep.** $279. The original computer-based pilot education product; video-lecture format with Martha and John King (now joined by additional instructors per the 2024 course update). Free lifetime course access and automatic updates; test-pass guarantee. The conversational, prose- forward Kings style is pedagogically distinctive and has been the practitioner default for the knowledge-test path for thirty years. The 2024 update added an additional instructor and updated the avionics content; the underlying pedagogical approach is unchanged. - **Sporty's Instrument Rating Course.** Pricing varies by bundle; the standalone online course is in the $279–$329 range as of 2026, with a Deluxe Kit bundle (headset, kneeboard, plotter, E6B) at higher prices. The 2026 edition adds 13 hours of 4K IFR video filmed with a CFII in actual IMC; 27- maneuver guide; ChatCFI AI assistant for 24/7 questions. The Sporty's product is the production-value upgrade of the King Schools format — same scope, more polished, more video- forward, with the ChatCFI integration as the 2025–2026 differentiator. - **Pilot Institute — Instrument Rating Made Easy.** $279 (or $349 bundled with Checkride Ace). The recent (post-2018) entrant that has gained substantial market share among self-paced learners. 320+ bite-sized video lessons averaging 3 minutes each; real-world scenario training; mobile and offline access; 200+ flashcard cards; 900+ practice questions. Test-pass guarantee with $175 cash-back component. Practitioner reviews consistently rate it the best buy in the IFR ground-school market as of 2026. - **Gleim Aviation — Instrument Pilot Kit With Test Prep.** The classic book-and-software product; knowledge-test-focused rather than ground-school- focused. 2026 edition covers Airplane Instruments, Attitude Instrument Flying and Aerodynamics, Navigation Systems, FARs, Airports/ATC/Airspace, Holding and Instrument Approaches, Aeromedical Factors, Aviation Weather, Aviation Weather Services, and IFR En Route and IFR Flights. 950+ practice questions; FAA test prep online; flight bag. The Gleim approach is question-bank-driven and is criticized within the field on the same teaching-to-the-test grounds that SUBJ-003 §III surveyed for the Private Pilot equivalent. It remains the test-prep-only choice for

many self- studiers who already have ground-school exposure. - **ASA — *The Complete Instrument Rating Knowledge Test* and *Instrument Pilot* textbook (Eckalbar or current author).** Book-and-software competitor to Gleim. Comparable scope and pedagogy. ASA's test-prep books are widely used in Part 141 schools alongside the school's primary ground-school product.

The five products converge on the FAA's published IRA question bank as the operational test target. The "everyone studies the question bank" critique is real for the IR as for the Private Pilot syllabus: the question bank is finite, partially public, and motivated test-takers can memorize question-answer pairs without acquiring the underlying conceptual understanding the ACS intends to test. Sheppard Air, popular in the ATP-CTP and airline community, is more aggressive about shortlisting the most likely questions; for the IR knowledge test, Sheppard Air's position is similar to the PPL — the test is passable in a weekend with the Sheppard book, but the result is calibrated correct answers without IFR-relevant understanding.

3.4 THE COMPREHENSIVE TEXTBOOKS

Beyond the test-prep packages, three reference textbooks deserve attention as standalone IR study material:

- **Jeppesen Sanderson — *Instrument/Commercial Manual*.** The Jeppesen instrument-and-commercial textbook used by many Part 141 schools that follow the Jeppesen curriculum. Comprehensive, integrated, illustration-rich. ~$200 retail. The textbook pairs with workbook and exam-prep materials. The Jeppesen approach is presented as a coherent semester course rather than as test prep, and the pedagogical scaffolding is more elaborate than the Gleim/ASA equivalents. Part 141 schools using the Jeppesen curriculum tend to be university-affiliated programs. - **Rod Machado — *Rod Machado's Instrument Pilot's Handbook*.** The prose-forward, humor-forward, pedagogically self-aware IFR textbook. Distinctive for its conversational explanation of approach procedures, its detailed treatment of the cognitive workload of single-pilot IFR, and its honesty about what the rating does and does not equip a pilot to do. Frequently cited within the practitioner community as the most pedagogically respectful of the available IR textbooks. The PI's local Dropbox contains the Machado IR Handbook (verified in SUBJ-003 inputs). - **ASA — *The Instrument Pilot* (Eckalbar or current author).** The standard ASA full-syllabus textbook. Used widely as an adjunct to test-prep products. Comparable to Jeppesen in scope; more textbook-conventional in tone.

3.5 THE PILOTWORKSHOPS RECURRENT TRADITION

The **PilotWorkshops IFR Mastery** subscription is the most-discussed example of a post-rating recurrent- training mechanism. The model — interactive monthly scenarios in which the pilot evaluates weather, performance, charts, regulations, and operational risk before choosing a course of action, followed by instructor roundtable discussion of the choice — is designed explicitly for the working IFR pilot rather than the IR student. Subscription is $24/month as of 2026; the archive now contains 280+ VFR and IFR scenarios. Sporty's integrated the Mastery library into its Pilot Training app in May 2026, broadening distribution. Completed scenarios qualify for FAA WINGS credit.

The PilotWorkshops format is the cleanest practitioner implementation of the lab's W2-004 expertise-adaptive scaffolding findings applied to recurrent training: each scenario is short, requires active prediction before the resolution, and includes the multi- instructor disagreement that makes the judgment dimensions visible. The lab's W2-001 spacing-and- interleaving prediction maps

cleanly onto the monthly-scenario cadence. The Mastery product is, in the agent's assessment, the most pedagogically sophisticated recurrent-training mechanism for GA IFR pilots currently on the market; the limitation is that scenario-based training is supplement, not substitute, for the actual-IMC and simulator-based recurrent practice the IPC tradition codifies.

3.6 THE AOPA AIR SAFETY INSTITUTE LIBRARY

The AOPA Air Safety Institute provides free online courses, case studies, and recurrent-training material to AOPA members. The IR-relevant subset includes the *IFR Insights* series, the *Real Pilot Story* case- study videos (many of which are IR-pilot incidents), the *Weather Wise* series of online modules on icing and convective avoidance, and the *IFR Mastery* and *Single Pilot Resource Management* courses that overlap (with similar names but different content) the PilotWorkshops product. AOPA ASI's pedagogical discipline is case-study-driven; the courses are short, scenario-focused, and free; they qualify for WINGS credit. The AOPA ASI material is the lab's best evidence of practitioner-grade Layer-3 and Layer-4 training content delivered at scale to a working-pilot audience.

3.7 THE CIRRUS CSIP PATHWAY AND TYPE-SPECIFIC TRAINING

The **Cirrus Standardized Instructor Pilot (CSIP)** program is the most influential type-specific IR pedagogy infrastructure for GA single-pilot operations. The CSIP network is the Cirrus-trained and Cirrus-certified instructor body; the Cirrus Transition Course is the standard 3-day VFR-to-Cirrus checkout; the Cirrus Instrument Rating Program at the Cirrus Approach learning platform is the type-integrated IR curriculum for pilots training in Cirrus airframes. The CSIP curriculum is built on scenario-based training and on explicit practice with the Perspective+ panel, the GFC 700 autopilot, the CAPS decision-making framework, and the type-specific emergency procedures. The Cirrus Instrument Rating Program at Cirrus Approach (cirrus-approach.com) is the formal IR syllabus for the type; the airframe is the avionics rather than the airframe alone.

Comparable type-specific programs exist for other airframes — the American Bonanza Society's Beechcraft Pilot Proficiency Program (BPPP) for the Bonanza and Baron line, the Mooney Owners' Association programs, the COPA Cirrus Pilot Proficiency Program for recurrent Cirrus training, the Diamond Aviator's Club recurrent programs. These are recurrent-training infrastructures more than they are primary-IR training programs; the BPPP especially has a multi-decade record of correlating with reduced accident rates among type-specific pilot populations (though the selection-bias confound — pilots who sign up for BPPP are systematically different from those who do not — limits causal interpretation).

3.8 SCHOOLS AND PATHWAYS

The U.S. IR training market splits along the same four-pathway taxonomy as primary training, with modified weight distributions:

Part 61 — small school and independent CFII. The dominant pathway for the recreational IR student. A single CFII with IFR currency and a single IFR- equipped airplane suffices to provide the training. 40-hour legal minimum to the IR for an existing Private Pilot (14 CFR 61.65(d)). The flexibility is the strength; the variance in instructor quality and syllabus rigor is the weakness. The PI's local options at KMIE — Rapid Flight Training and Muncie Aviation's flight department —

are Part 61 operations that offer IR training; the SUBJ-003 returning-pilot- guide identified RFT as the Cirrus-specialist operator and Muncie Aviation as the broader-fleet operator.

Part 141 — structured-syllabus school. Reduced flight-time minimum (35 hours rather than 40, per 14 CFR Part 141 Appendix C). FAA-approved syllabus, defined phase checks, chief CFI oversight. Faster on average; more expensive on a per-hour basis; more time-discipline-demanding. Jeff Air at KAID operates a Part 141 IR program for the local recreational student. University aviation programs (Embry-Riddle, Purdue, UND, Auburn, Indiana State) and the airline-pipeline academies operate at the high-volume end of Part 141. The 5-hour minimum reduction is the visible delta; the structured syllabus and phase-check discipline are the hidden delta, and the practitioner consensus is that the Part 141 graduate is somewhat better-trained at the same flight-hour count, though no rigorous outcome study supports this confidently.

The accelerated-program pathway. Two-week and ten-day IR programs offered by specialist operators — Professional Instrument Courses (PIC), IFR West, Aviation Training Resources, and similar. Cost in 2026 runs $7,500–$12,000 depending on airframe and location; the student must arrive with the 40 hours of cross-country and most of the ground-school material complete. The pedagogical case for acceleration is the consolidation argument (the deep schema-building that comes from intensive exposure across consecutive days); the pedagogical case against is the lab's W2-001 spacing finding (distributed practice produces better long-term retention than massed practice). The empirical evidence is, as SUBJ-003 §III noted for primary training, mostly practitioner consensus rather than rigorous outcome comparison.

The airline-pipeline pathway. ATP Flight School, Mesa Pilot Development, Republic LIFT Academy at KIND, and similar operations integrate the IR into a Commercial Multi-Engine Instrument program ending with CFI/CFII certification. ATP's 2026 cost from zero to commercial multi-engine instrument is $123,995, or $90,995 starting with a private pilot certificate; the program runs 9–11 months. The IR is incidental to the program rather than its endpoint; the IR-pilot product is a future airline pilot, not a recreational instrument pilot. This pathway is out of scope for the PI's stated GA-not- airlines framing but defines the market for IR recurrent training: many of the ATP-pipeline graduates become CFIIs who then teach IR to the recreational Part 61 student.

Type-specific training programs. The Cirrus Vision Center at McGhee Tyson (KTYS), Embry-Riddle's Cirrus-equipped program, and various Cirrus-aligned flight schools provide Cirrus-specific IR training that integrates the type-checkout, the Perspective+ familiarity, and the IR syllabus. Pricing runs at the higher end ($14,000–$22,000 for the IR) but the integration produces a graduate who is operationally fluent in the airframe they will fly post-rating — a meaningful gap closure for the working-IR-pilot competence the agnostic Part 61 or 141 program may not address. FlightSafety, CAE, and SimCom operate at the turbine-airframe end (SR22T, TBM, Vision Jet, King Air) and are discussed below in the simulator section.

3.9 THE CENTRAL-INDIANA CASE STUDY

A grounded illustration of the IR-school landscape for the PI's specific context (drawn from the SUBJ-003 returning-pilot-guide and updated with IR-specific verification):

- **Rapid Flight Training (KMIE)** advertises an accelerated IR program; the SR20 in the fleet supports type-aligned training; Matt Lehtinen is the CSIP-network operator for central Indiana. IR-specific pricing not published; phone-verify. [**phone-verify**] - **Jeff Air Pilot Services (KAID)** operates both Part 61 and Part 141 IR pathways using the 172 fleet; the on-site simulator at $250/year access fee is the cheapest local procedural-practice option. [**phone-verify**] - **Muncie Aviation Flight Department (KMIE)** has three CFIs on staff with CFII credentials (Shoup, Glassburn,

Walker per SUBJ-003 returning-pilot- guide §IV); deeper bench but historical focus on Piper, TBM, and Kodiak transition training rather than ab initio IR. [**phone-verify**] - **LIFT Academy at KIND** is airline-pipeline only; not the PI's path. - **Indiana State (Terre Haute, ~75 NM W of KMIE)** operates a Part 141 aviation program with IR training; relevant to the PI's son's potential future training (per SUBJ-003 sons-primer) but not the PI's near-term path.

The agent's tentative recommendation for the PI's IR pathway is laid out in `pi-ir-curriculum.md`. The short version: Part 61 indie-CFII path at RFT with the SR20 for the type-aligned end-state, supplemented by inexpensive simulator and 172 time at Jeff Air for the procedural-practice and scan-fundamentals phase, plus PilotWorkshops IFR Mastery and AOPA ASI recurrent material throughout.

3.10 A PEDAGOGICAL ASIDE

As SUBJ-003 §II noted for primary training, the curriculum-versus-outcome literature for IR training is strikingly thin. There is no rigorous comparative outcome study of Part 61 versus Part 141 IR graduates' post-rating safety records, of accelerated versus long-tail IR programs' long-term proficiency retention, or of the major commercial ground-school products against measurable learning outcomes. The field operates on the same practitioner-consensus basis SUBJ-003 surveyed for primary training; the lab's W2-001 spacing prediction applies to IR training as much as to primary training and produces the same plausible-but-untested hypothesis (that long-tail weekend-cadence training should produce better long-term retention than 10-day accelerated training). The IR-specific outcome study that the field has not produced would be a high-value lab contribution.

4

PART III — PEDAGOGICAL APPROACHES AND THE CONTROVERSY MAP

The IR pedagogy literature is even thinner than the primary-training pedagogy literature SUBJ-003 §III surveyed. The frameworks the FAA mandates are mostly the same (PAVE, IMSAFE, 3P, 5P, SRM, the FITS scenario-based-training doctrine), and the same epistemic position obtains: rich at the framework level, thin at the rigorous-outcome level. The IR adds several disputes that primary training does not have because the IR is more tool-dependent, more workload-saturating, and more consequential when working competence is missing. The mandate calls this part the "controversy map." It is one of the IR's distinctive contributions to the lab's evidence- versus-opinion discipline, because the field is operating with more confidence than its evidence warrants on several pedagogically important questions. This part lays them out honestly.

4.1 AXIS 1 — PART 61 VERSUS PART 141

The pathway-choice question for IR training is operationally important and empirically underdetermined. The visible delta is 5 flight hours (35 vs 40 minimum). The structural delta is the syllabus and chief-CFI oversight model. The practitioner consensus is that Part 141 graduates are somewhat better-trained on a hours-equivalent basis, attributable to the structured syllabus discipline and the phase-check stops. As SUBJ-003 §III concluded for primary training, there is no rigorous comparative outcome study; the pathway- choice in 2026 is mostly a function of scheduling fit, geographic access, and learner preference.

For the recreational IR student the Part 61 indie- CFII path is more flexible, can be paced to the student's life, and typically costs ~10% less than the Part 141 equivalent at the same flight-hour count (because the Part 141 school is amortizing the syllabus development, chief-CFI overhead, and FAA- approval bureaucracy). For the airline-pipeline student, Part 141 is the standard pathway because the structured syllabus integrates better with the subsequent commercial-multi-instrument-CFI/CFII sequence and because the airline-pipeline academies are virtually all Part 141.

The lab's W2-001 spacing finding suggests that the *cadence* of training matters more than the *pathway* of training, and the cadence is set by the student's schedule rather than by the pathway choice. A Part 61 student flying twice a week with a single indie CFII will outperform a Part 141 student flying once a month, regardless of the syllabus.

4.2 AXIS 2 — SCENARIO-BASED VERSUS MANEUVERS-BASED TRAINING

The FAA pushed scenario-based training (FITS — FAA/Industry Training Standards) into IR pedagogy alongside Private Pilot pedagogy starting in the early 2000s. The FITS philosophy: replace isolated maneuver practice with realistic mission-context scenarios in which the pilot integrates instrument flying, navigation, ATC communication, and decision- making. For IR training the SBT logic is sharper because the rating's working application *is* mission flight in IMC; the maneuvers practiced in isolation (the hold, the approach, the partial panel) only make sense as components of a flight the pilot has filed, briefed, and is executing.

The empirical evidence base is the same body SUBJ-003 §III surveyed. Dornan et al. (2007) reported enhanced GPS proficiency under FITS for GA pilots; Ayers (2006) documented the FITS-SRM framework at Embry-Riddle; the Embry-Riddle "28% reduction in hours to commercial" claim should be read cautiously due to cohort selection. The Cirrus CSIP program is built on scenario-based training and the Cirrus Approach Instrument Rating Program is the cleanest production-grade implementation; the Cirrus accident-rate trends since CSIP rollout (a substantial reduction in fatal-accident rate per 100,000 hours over the past decade, per Cirrus and COPA data) are consistent with SBT working — also consistent with the parachute, the avionics evolution, and the type-club recurrency program operating in parallel.

The lab's W2-004 finding on expertise-adaptive scaffolding endorses the SBT direction explicitly: isolated maneuver practice produces brittle skill that does not transfer to the integrated mission; scenario-based practice produces the schema construction that does. The W2-004 prescription — explicit instruction for novices, faded scaffolding as schemas develop, productive failure for conceptual understanding, guided inquiry as expertise grows — maps cleanly onto the IR training sequence: explicit-procedure instruction in early lessons; faded scaffolding in mid-lessons; full-scenario integration in pre-checkride; the post-rating IPC and PilotWorkshops Mastery flow as the recurrent expertise-extending stage.

The honest summary: the FAA's FITS doctrine is right in direction and underdetermined in empirical detail. The Part 141 IR schools that have embraced SBT produce graduates the practitioner community judges to be better-prepared than the maneuvers-only-trained equivalent; the formal outcome study has not been done.

4.3 AXIS 3 — HAND-FLYING FIRST VERSUS AUTOPILOT-FIRST

The most consequential pedagogical dispute in modern IR training. The classical position: build the scan first, achieve full-panel and partial-panel proficiency to ACS tolerances, then add the autopilot as a workload-relief tool. The modern revisionist position: the working IR pilot will spend 80%+ of their IR time with the autopilot engaged; training that does not produce autopilot fluency from the start produces a pilot who is technically able to hand-fly but actually cannot manage the autopilot under workload, which is where the failures cluster.

The empirical case for the classical position rests on the Vanderburgh "Children of the Magenta" tradition (the airline-era warning about autopilot dependency degrading manual flight skill; American Airlines Flight Academy, late 1990s; now a practitioner-canonical YouTube reference) and on the broader automation-induced-complacency literature (Sarter, Woods, and Billings 1997; Sarter and Woods 1995). The empirical case for the revisionist position rests on Young, Fanjoy, and Suckow (2006) — which found that glass-cockpit- experienced student pilots had measurably *worse* manual flight skills than round-gauge-experienced peers under a controlled experimental design — and on the airline-pilot manual-flight degradation literature (Lefrançois, Matton, and Causse 2021 on improving manual flight via skilled-eye-gaze training; Bjorklund, Alfredson, and Dekker 2006 on mode monitoring).

The synthesis the field has converged on is something like: build the scan and partial-panel work first (~10 hours of focused hand-fly time under the hood), then introduce the autopilot as a *deliberate workload-management tool*, with explicit practice at all three Vanderburgh-levels every flight (full automation, flight director only, hand-flown). The Cirrus CSIP syllabus explicitly embodies this — the CSIP-required exercises include hand-flown coupled-approach disconnections at mins, FD-only ILSes, and full manual approaches under partial-panel conditions. The empirical case for the synthesis is the type-club accident-rate trend (Cirrus and Bonanza fleets that adopted

CSIP/BPPP recurrency show measurably lower fatal-accident rates than the fleet-wide average), mediated by selection bias of unknown magnitude.

The lab's W2-005 metacognitive-laziness finding — that tools doing the work for the learner degrade the learner's capability while improving immediate task performance — applies here. The autopilot-first training pathway is the W2-005 failure mode if it allows the student to skip the scan-building work; the autopilot-as-workload-tool synthesis preserves the scan competence while building autopilot fluency. The honest summary: train the scan first, introduce the autopilot deliberately, never let the autopilot use degrade into autopilot dependency. The practitioner consensus is in this direction; the rigorous outcome evidence is thinner than the consensus.

4.4 AXIS 4 — ROUND-GAUGE VERSUS GLASS-COCKPIT PRIMARY TRAINING OF THE SCAN

A specific instance of Axis 3. The classical claim: the round-gauge "six-pack" panel forces a more robust scan because the pilot must integrate information across six discrete instruments rather than reading it off a single PFD; the resulting scan schema transfers to any cockpit. The revisionist claim: the modern working IFR cockpit is glass, the glass scan is what the pilot needs, training on a steam-gauge panel builds the wrong schema for the actual working environment.

The empirical case is again thinner than the disputants' confidence suggests. The NTSB safety study NTSB/SS-10/01 (2010) found that glass- cockpit aircraft were in fewer total accidents than their fleet share but in *more* fatal accidents, attributable to automation surprise, mode confusion, and complacency. AC 90-109A codified the TAA transition framework around this finding. Young, Fanjoy, and Suckow (2006) found that glass-trained students had worse manual flight skills under controlled testing. Lounis, Peysakhovich, and Causse (2021) found that pilot expertise modulates visual scanning strategy in ways that suggest scan training produces durable expert patterns regardless of the primary instrumentation. Škvareková and Škultéty (2019) measured pilot attention during IFR flights using eye-tracking and found systematic scan differences between high- and low-experience pilots in actual IFR cockpits, consistent with scan as a developing expertise rather than as a configuration-dependent skill.

The synthesis: the scan as a cognitive skill is substantially configuration-independent; the specific instrument-layout knowledge is configuration-specific. A pilot who builds the scan on round-gauges and transitions to glass needs ~5–10 hours of glass-specific work to recalibrate the scan to the PFD's information layout; a pilot who builds the scan on glass and transitions to round-gauges needs ~5–10 hours of round-gauge work and somewhat more work to build the cross-instrument integration the round-gauge panel demands. The 2026 modal CFII would train in the airframe the student will fly post-rating and is right to do so.

The lab's W2-004 expertise-adaptive-scaffolding finding offers a useful clarification: the *novice IR pilot* benefits from the more cognitively demanding round-gauge scan because the cognitive load forces deliberate, attended scan acquisition; the *intermediate IR pilot* benefits from the faded-scaffolding step into glass, where the PFD's consolidated display reduces extraneous cognitive load and frees capacity for procedure management. The pedagogical sequence — start round-gauge if possible, transition to glass for the working cockpit — has more theoretical support than the practitioner literature gives it.

4.5 AXIS 5 — FULL-MOTION SIMULATOR VS AATD VS AIRCRAFT-ONLY TRAINING

The IR is the most simulator-tractable rating in the FAA system because most of the skill base is procedural and instrument-reference rather than seat-of-the-pants. The 14 CFR 61.65(d) and Part 141 Appendix C frameworks specify the hours that may be substituted with approved simulators:

- **Full-motion Level D / Level C simulators** are reserved for type-rated turbine training and are not relevant to the GA-IR pathway. - **Advanced Aviation Training Devices (AATDs)** qualify for substitution of up to 20 hours of the 40-hour instrument-time requirement under Part 61, per 14 CFR 61.65(i). The Redbird FMX and the Frasca Mentor are the dominant AATD products in 2026; cost is ~$50–$150/hour at flight schools that have them. - **Basic Aviation Training Devices (BATDs)** qualify for substitution of up to 10 hours under Part 61. The Redbird Jay and Elite RC-1 are representative; lower fidelity, lower cost. - **Consumer simulators** (Microsoft Flight Simulator, X-Plane, Prepar3D) qualify for zero logged hours but are widely used for procedural rehearsal and are increasingly augmented with VATSIM ATC for radio-fluency practice.

The empirical transfer evidence is the same body SUBJ-003 §III surveyed. Roscoe (1980) established Transfer Effectiveness Ratio as the metric; Korteling, Helsdingen, and Sluimer (2016) provided the cleanest single empirical study on consumer- simulator transfer (Falcon 4.0 produces both near and far transfer; MSFS produces only far transfer — that is, MSFS builds vocabulary, procedural familiarity, and contextual fluency but does not substitute for the embodied learning of the target activity). Somerville et al. (2025) meta- analyzed extended-reality pilot training across 67 articles and found a moderately strong overall effect ($d = 0.88$, $p = 0.025$) with simulator- sickness caveats. Rizvi et al. (2025) found augmented-reality applications in FSTD training showed positive technology acceptance among GA pilots. White et al. (2021) reviewed flight- simulator fidelity requirements for rotorcraft loss-of-control training and concluded that higher fidelity does not always produce better training outcomes — the cognitive-load match between simulator and task is the more discriminating variable.

The synthesis for IR training: the AATD or BATD is appropriate for procedure rehearsal (programming the GPS, briefing the plate, flying the approach geometry, executing the missed-approach, holding entry) where the cognitive load is procedural and the airplane's response is unimportant; the airplane is required for the kinesthetic and workload-integration components where the real-cockpit feedback matters; the consumer simulator augments the AATD by extending procedural rehearsal to home environments at zero marginal cost. The agent's recommendation for a 2026 IR student: do 8–15 hours of AATD work as part of the 40-hour instrument time requirement (maximizing the 61.65(i) substitution where the school has an FAA-approved AATD); supplement with weekly consumer-sim home rehearsal at ~30 minutes per session; reserve the airplane time for the integrated-scenario, workload-saturating, actual- IMC-equivalent training that only the airplane delivers.

4.6 AXIS 6 — THE 160-HOUR WONDER

The single most consequential disagreement in the IR pedagogy community. The "160-hour wonder" is the practitioner term for the newly-rated IR pilot at or near minimum hours (a Private Pilot at 100 total time + 40 IR training hours = 140 hours; a more typical "minimum" path runs 160–200 hours) who has passed the checkride but is not in fact ready to fly hard IFR in actual IMC. The accident data are consistent with this: per the AOPA Air Safety Institute McSpadden Report's IR-pilot breakdown, instrument-rated pilots at low total hours have elevated fatal-accident rates in IMC- involving accident categories — though the selection-bias confound is real (the pilots who

get the rating early and fly hard IMC are systematically different from those who get the rating later and fly conservative IMC).

The field has converged on a partial remediation through several mechanisms:

- The **Instrument Proficiency Check (IPC)** required under 14 CFR 61.57(d) after a 6-month beyond-currency-lapse window. A 4–6-hour comprehensive workout with a CFII; reset the currency clock; expose the gaps. - **Type-club recurrency programs** (Cirrus CSIP- network annual recurrence; Bonanza Pilot Proficiency Program 3-day annual; Mooney M20 club programs). Concentrated 2–3 day immersive recurrent training; consistently associated with reduced fatal-accident rates among type-club participants (selection-bias confound noted). - **The PilotWorkshops IFR Mastery subscription** and the AOPA ASI IR-specific case-study courses. Monthly scenario-based recurrent thinking practice; not a substitute for stick-and-rudder but a meaningful supplement. - **The "phase" structure of post-rating IFR exposure**: structured progression from benign-IMC departures with high ceilings, through benign-IMC approaches at home airports, to marginal-IMC cross-country, to challenging-IMC conditions, with self-imposed personal-minimums walked down deliberately over months and years. - **The "fly with a more experienced pilot" pattern**: many GA-IR pilots intentionally fly their first 20–50 actual-IMC hours with a CFII or experienced safety pilot in the right seat, paying the social cost of an extra seat in exchange for the working-competence safety net.

The pedagogical question is whether any of this should be *built into the regulatory floor*. The FAA's position has been that the recurrent mechanisms exist and are voluntary; making them mandatory would face industry resistance and substantial regulatory complexity. The practitioner counter-position is that the voluntary regime leaves the 160-hour wonder problem unaddressed for the segment of pilots who would benefit most from mandatory recurrent training (the self-selected segment who skip voluntary recurrent are the segment with the highest accident risk). The lab's COMPETENCE- TARGET.md framing on environmental design applies: a regulatory environment that does not require working-competence demonstration creates incentives for pilots and schools to optimize for checkride-day competence at the expense of working competence.

The agent's assessment: the field has the partial remediation mechanisms; the regulatory floor does not require them; the working IR pilot is responsible for their own recurrent discipline; the gap closure depends on whether the individual pilot has the metacognitive honesty (Layer 4) and character disposition (Layer 5) to invest in the recurrent work. This is the lab's central interest — upper-layer competence formation — applied to a canonical regulated-competence domain. The IR is one of the cleanest civilian instances of a domain where the regulatory floor is acknowledged inadequate and the field has accumulated a partial remediation infrastructure, without yet closing the gap.

4.7 AXIS 7 — APPROACH-PLATE PROFICIENCY: PAPER, FOREFLIGHT, GARMIN PILOT, AVIONICS DATABASE

The pedagogical question: in what sequence should an IR student build approach-plate fluency? The classical claim: start with paper plates so the student learns the symbology in isolation, then move to digital. The revisionist claim: the working IR pilot will fly almost exclusively from ForeFlight (or Garmin Pilot), so train on ForeFlight from the first lesson and let the symbology familiarity build through use.

The empirical evidence is essentially zero. The plate-symbology fluency literature is one of the thinnest pedagogical literatures in aviation training; the practitioner consensus is divided. The lab's W2-001 finding on retrieval practice plus the W2-004 finding on expertise-adaptive

scaffolding suggest a middle path: introduce plates on paper for the symbology study (one-page plate at the kitchen table, work through the briefing strip, the plan view, the profile view, and the missed-approach text element by element), then introduce ForeFlight as the working-cockpit tool from the first hood lesson. The pedagogical function of paper is the initial symbology acquisition; the working tool is digital. The sequence: paper for learning, digital for using. This is roughly the synthesis the CSIP curriculum adopts.

4.8 AXIS 8 — WHAT TO FLY IFR IN

The single most consequential non-recurring decision the IR pilot makes. The choice of airframe determines the operating envelope on the days the pilot actually intends to use the rating.

The taxonomy:

- **Light single, non-FIKI, normally aspirated** (Cessna 172 with IFR-equipped 530W or G1000, Cherokee/Warrior, Diamond DA40, Cirrus SR20). Useful IFR envelope: benign IMC, summer thunderstorm avoidance via deviation, en-route altitudes below the icing layer or above it (depending on airframe ceiling), no known icing, no embedded convection. The envelope is real but constrained; the pilot must scrub frequently in the winter half of the year. Cost: low. - **High-performance single, non-FIKI, normally aspirated** (SR22 normally aspirated, Bonanza, Mooney M20J). Extended envelope: higher altitudes available (more above-the-layer options), faster cruise (more responsive weather avoidance), but still no FIKI. Cost: moderate. - **High-performance single, FIKI-certified, turbocharged** (SR22T with FIKI, Bonanza with FIKI). Substantially extended envelope: known icing approved (within FIKI envelope and pilot judgment), high-altitude IFR available, full IFR utility for personal travel. Cost: high. - **Turbine single** (Cirrus Vision Jet, TBM 940, Pilatus PC-12). Full FIKI plus high altitude plus reliability plus speed. Cost: very high; requires the type-rating training infrastructure (FlightSafety, CAE) for recurrency. - **Twin piston** (Beech Baron, Piper Seneca, Beech Travel Air). Engine-out redundancy plus somewhat extended icing capability (some twins are FIKI). Cost: high in operation due to twin-engine fuel and maintenance; requires Multi-Engine Instrument rating and MEI proficiency.

The decision the IR pilot must make is what fraction of their planned IFR mission profile requires which envelope. A pilot who intends to fly recreational weekend cross-countries in the Midwest in good weather, using IFR for the convenience of structured ATC and the legal ability to penetrate occasional layers, is well- served by the light-single non-FIKI option. A pilot who intends to use the rating for actual travel through actual weather year-round is not. The PI's stated profile (recreational utility, GA not airlines, Midwest, no urgent get-there-pressure) maps to the light-single non-FIKI option; the SR20 the PI has access to at Rapid Flight Training is exactly this airframe. The PI's IR is functionally useful for the shoulder-season IMC, the morning-fog approaches, the post-front low-ceiling departures, and the en-route layer-penetration. It is not useful for winter icing flying, embedded thunderstorm penetration, or any flight where the pilot's preferred operating envelope requires the FIKI or turbine extension. The honest framing of the PI's IR pursuit should acknowledge this from the start; the pi-ir-curriculum.md treats it explicitly.

4.9 AXIS 9 — THE PBN/RNAV/WAAS TRANSITION

The 2000-era IR was VOR/ILS-dominant; the 2026 IR is GPS/RNAV/LPV-dominant. WAAS-LPV approaches now exist at over 4,100 runway ends in the United States (FAA WAAS Quick Facts, 2024), with minima as low as 200 feet AGL and half-mile visibility — approaching ILS minimums. LNAV+V advisory vertical guidance is now standard at WAAS-equipped airports. The IR pilot

must understand the distinction between LPV (approach guidance with vertical lateral integrity), LNAV/VNAV (baro-VNAV or WAAS-VNAV approach guidance), LP (Localizer Performance, lateral-only with WAAS), LNAV (non-precision lateral-only), and LNAV+V (LNAV with advisory vertical that is *not* approach guidance — the load-bearing safety distinction the FAA has issued safety notices about).

The pedagogical question: how much of the legacy VOR/ILS skill base should the modern IR student build? The classical position: full historical fluency — VOR airways, the procedure turn, the DME arc, the localizer-only approach. The revisionist position: train to current operational reality — RNAV airways, direct routing, the LPV approach, the GPS-overlay approach — and reduce the legacy material to recognition-only depth.

The synthesis: the ACS still tests both, so the student must be checkride-fluent in both; the working pilot can be operationally fluent primarily in the modern (GPS/RNAV/LPV) workflow because that is what the working cockpit delivers. The legacy material is for the unusual-circumstance scenario (the GPS receiver fails; the WAAS signal degrades; the airport has only an ILS or VOR approach). The 2026 modal CFII trains both, weights toward the modern, and expects the working-pilot's daily use to be the modern. AIM Chapter 1-2 (Performance-Based Navigation and Area Navigation) and AC 90-105 (PBN operations) are the current reference documents.

4.10 AXIS 10 — AI-ASSISTED STUDY AND AI IN THE COCKPIT

As of 2026, large-language-model assistants are real study aids for the IR written and oral. The FAA's position on AI in flight training is evolving; the Sporty's IR course now bundles ChatCFI as an integrated AI assistant; many self-studiers use Claude, ChatGPT, or Gemini directly for ground-school explanation, regulatory lookup, POH content interpretation, and oral-exam scenario practice.

The W2-005 metacognitive-laziness concern applies in stronger form for the IR than for the PPL: the AI can produce a plausible but wrong answer about a specific regulation, an approach procedure, or an autopilot mode behavior with high fluency; a student who outsources the interpretation to the AI may not catch the hallucinated section number or the misstated procedure. The aviation-domain risk is sharper because the consequences of operating on a hallucinated procedure in IMC are immediate and potentially lethal.

The responsible-use pattern for IR study is the W2-005 prescription applied carefully:

- Use the AI to *explain*, *query*, and *probe* the material the student has read. The "explain this AIM section to me in plain language" use is appropriate. The "summarize 14 CFR Part 91 Subpart B so I don't have to read it" use is the metacognitive-laziness failure mode. - Verify regulatory citations against the eCFR text and AIM citations against the current AIM before acting on AI-generated answers. - Use the AI for active-retrieval scenarios where the AI presents a scenario and the student answers, with the AI cross-checking against references. The PilotWorkshops Mastery format is an early implementation of this approach; the Sporty's ChatCFI is a less-structured variant. - Treat the AI's output as practitioner-confidence source, not as authoritative source. The cheat-sheet's pointer-set lives in the FAA documents, not in the AI conversation.

The honest summary: AI is a useful adjunct, not a substitute, for the IR study workflow. The discipline of verification is the metacognitive practice that lets AI augment rather than degrade the student's competence.

4.11 CROSS-AXIS SYNTHESIS

The ten controversies above cluster around a few deeper patterns:

1. **The IR is the GA pedagogy's hardest case for the upper-layer competences.** The Layers 1 and 2 material is well-codified; Layers 3, 4, and 5 are where the field's failure modes cluster and where the field's recurrent- training apparatus has been working for decades without yet closing the gap. This is the lab's central interest, applied to a canonical regulated-competence domain. 2. **The empirical-evidence base is thinner than the practitioner-consensus confidence suggests.** The IR pedagogy frameworks (FITS, PAVE/IMSAFE/3P/5P, SRM, TEM, the named automation-management doctrines) are regulatorily mandated and broadly accepted without rigorous outcome evaluation. The lab's discipline of distinguishing evidence from opinion applies to almost every IR-specific claim made in the field. 3. **The technology is moving faster than the pedagogy.** The 2026 cockpit (GPS/RNAV/LPV dominant, glass primary, autopilot with VNAV and coupled-approach capability, EFB-integrated workflow) is different enough from the 2005 cockpit that the inherited pedagogy is pulling its punches. The Advanced Avionics Handbook (FAA-H-8083-6, 2009) is a documentation gap that the field has not closed. 4. **The selection bias on every claimed effect is unresolved.** Type-club recurrency programs correlate with reduced fatal-accident rates; the pilots who participate are systematically different from those who do not. Part 141 schools produce graduates the field judges better-prepared; the students who choose Part 141 are systematically different from those who choose Part 61. The IR pilot who trains in glass arrives at the checkride differently than the one who trains in steam gauges; the selection of training airframe is correlated with the pilot's eventual mission. The field's outcome inferences are correlations, not causations. 5. **The honest position is to teach the pedagogical reasoning, not the pedagogical dogma.** A CFII who explains *why* the scan should be built before the autopilot is added — the cognitive-load and skill- acquisition theory — gives the student a framework for evaluating their own development. A CFII who simply asserts "we train scan first" gives the student a rule without the basis to apply it in non-prescribed conditions. The lab's W2-009 psychological-safety finding endorses the explanation-over-assertion pedagogical style.

The controversy map is not a closed account. Several of the disputes named here will be empirically tractable as the field matures (the Cirrus accident-rate trend data, the PilotWorkshops Mastery longitudinal outcome data, the FAA's NextGen-era safety statistics) and should be revisited in 2030.

5

PART IV — TOOLS

The IR is more tool-dependent than primary training. The working IR pilot is fluent across an avionics suite, an autopilot, an EFB, a weather product ensemble, an approach-plate library, a checklist tool, and (for many) a recurrent simulator. The fluency under workload — not the configured fluency in calm conditions — is what distinguishes the working pilot from the checkride pilot. This part surveys the tool stack as it stands in 2026.

5.1 AVIONICS PLATFORMS

The IFR-cockpit avionics landscape in 2026 is a generational stack rather than a single product. The major platforms:

- **Garmin GTN 750Xi / 650Xi.** The dominant current-generation Garmin GA navigator. Touch-screen interface; WAAS-enabled; integrates with ForeFlight via Bluetooth; the standard upgrade path for owner-flown GA airplanes since approximately 2020. The GTN family replaces the GNS 430/530 generation; the operating logic is related but distinct, and the GNS-to-GTN transition is a real training delta for legacy pilots. - **Garmin GNS 430W / 530W.** The legacy WAAS- capable Garmin GA navigator. Still installed in thousands of GA airframes; many rentals and flight-school airplanes still have these. Operationally adequate for IFR but with the pre-touch interaction model the GTN replaced. - **Avidyne IFD 440 / 540 / 550.** The principal Garmin competitor; designed as a plug-and-play replacement for the GNS 430/530 in retrofit installations. Touch-screen plus hardware controls; WAAS-enabled; FMS-style flight planning logic. - **Cirrus Perspective+ (Garmin G1000-NXi base).** The integrated glass cockpit in Cirrus SR20/SR22 airframes from 2017 onward. PFD with synthetic vision, MFD with engine page and map, GFC 700 autopilot integration, dual MFD or panel-mount GTN configurations depending on year and option. - **Garmin G1000 / G1000 NXi.** The integrated glass cockpit in Cessna 172/182/206, Diamond DA40/DA42, and many other airframes. NXi is the current generation; pre-NXi G1000 cockpits remain in service. - **Garmin G3X Touch.** Garmin's experimental- category-certified glass cockpit; increasingly installed in certified airframes under Garmin's STC pathway. Different interaction model from the G1000. - **Aspen Avionics PFD.** The PFD-only retrofit product; replaces the attitude-and-heading- indicator pair in legacy round-gauge airframes. Useful intermediate step between full round- gauge and full glass. - **Standalone Garmin G5 / G500 TXi.** The standalone PFD/MFD products for owner-installed retrofits.

The IR-training implication: the cockpit the student trains in determines the cockpit-specific fluency the student builds. The platform-agnostic IR knowledge (regulations, approach-plate fluency, weather product interpretation, ATC procedures) is substantially platform-independent; the platform- specific fluency (which knob loads the approach, how the autopilot captures the glide path, how reversion mode is engaged, what the LP-LNAV-VNAV- LPV annunciations look like) is platform-specific and is the source of much of the working-pilot competence gap.

5.2 AUTOPILOTS

The autopilot is the IR cockpit's most consequential single subsystem. The major products:

- **Garmin GFC 500.** The current-generation experimental and Part 23 retrofit autopilot. HDG, NAV, APR, ALT, VS, FLC, VNAV modes; GPSS steering; LVL panic mode in some configurations. The GA-recurrent autopilot growth story of 2020–2026. - **Garmin GFC 700.** The integrated autopilot in G1000-NXi and Cirrus Perspective+ installations. Tightly coupled with the avionics suite; the same mode taxonomy as the GFC 500 plus manufacturer-specific extensions (the Cirrus ESP envelope protection, the LVL blue-button). - **S-TEC 30 / 55X / 3100.** The principal legacy autopilot family in pre-2015 GA airframes. The 3100 is the modern digital iteration; the 55X is the long-running analog product still in many SR20s and Bonanzas. - **Bendix/King KAP-140 / KFC 200 series.** The Cessna factory autopilot in many post-2005 C172s and the legacy Bendix/King product in much of the older GA fleet. - **Avidyne DFC 90 / DFC 100.** Avidyne's autopilot family; coupled with the Avidyne IFD navigator and with the Aspen PFD.

The autopilot-fluency competence requires for each product: the mode taxonomy and what each mode does; the cross-coupled-mode behavior (NAV+ALT vs APR+ALT vs FLC alone); the disconnect procedure (yoke button, panel button, throttle quadrant button); the engage-after-disconnect procedure; the failure- mode-and-reversion behavior; the autopilot-induced nuisance failure modes (mistrim during disengage; runaway trim; mode reversion after a heading bug change). The Cirrus CSIP curriculum drills these explicitly; the typical Part 61 IR student picks them up incidentally and incompletely.

5.3 ELECTRONIC FLIGHT BAG (EFB) APPS

ForeFlight is the dominant EFB in U.S. GA. For IR-specific functionality the relevant features are: plate organization and presentation (the "Procedure Advisor" automatically arranges approach plates by likely sequence for the filed route); the IFR brief (weather, NOTAMs, and route-specific information in a single integrated package); the in-flight weather overlay (FIS-B or ADS-B In integration); the performance and weight-and-balance modules for airframe-specific configurations; the integrated flight logbook. Subscription is in the $99–$299/year range depending on tier.

Garmin Pilot is the principal alternative, particularly for owners of Garmin avionics; feature parity is high. Subscription is $79–$249/year.

FltPlan Go (Garmin-acquired) is the legacy free alternative with smaller market share.

SkyDemon dominates the European GA EFB market; not common in U.S. GA but worth knowing about for international operations.

The working IR pilot's EFB workflow runs from flight planning through filing through briefing through in-flight situational awareness through post-flight logbook update; the EFB is the operational center of gravity for the trip. The cheap-to-master subset (filing the plan, briefing the weather, accessing the approach plates, reading the in-flight FIS-B weather) is what the IR student should be fluent in before the checkride; the deep-customization subset (custom checklists, performance profiles, integrated W&B) is what the working pilot adds in the first year post-rating.

5.4 SIMULATORS AND ATDS

Already covered in §III Axis 5. The summary table:

Class	Realism	Logging credit	Cost	Primary IR use
Level D	Very high	High (type rating); not GA	$300+/hr commercial	Turbine type-rating; not GA-
AATD (Redbird FMX, Frasca Mentor)	High procedural	Up to 20 hours under 14 CFR 61.65(i)	$50–$150/hr	IR procedure rehearsal, plate
BATD (Redbird Jay, Elite RC-1)	Medium procedural	Up to 10 hours under Part 61	$25–$75/hr	Basic procedure rehearsal
MSFS / X-Plane home rig	Variable	None	$500–$2,000 one-time	Procedural rehearsal, plate fl
MSFS + VATSIM / PilotEdge	Variable	None	Same + free/subscription	ATC fluency, radio rhythm
VR home rig (Quest + yoke + pedals)	Medium	None	$1,500–$3,500	Procedure + visual immersio

The empirical transfer evidence (Korteling et al. 2016; Somerville et al. 2025; Rizvi et al. 2025; White et al. 2021) supports the working synthesis laid out in §III Axis 5: AATD for logged procedural work; consumer simulator for unlogged procedural rehearsal at home; airplane for the integrated workload-saturating actual-IMC- equivalent training.

5.5 ATC SIMULATORS

PilotEdge is the paid online-ATC simulator network. Live human controllers; substantial U.S. West coverage; the closest-to-operational-realism ATC simulator available to consumer pilots. Subscription is in the $20–$30/month range.

VATSIM is the volunteer-staffed alternative. Worldwide coverage; controller availability varies by region and time; free; pilot must use one of several flight-simulator clients (vPilot, xPilot) to connect. Coverage in the U.S. is best in metro-area sectors and during evening-and-weekend hours.

FSEconomy / IF1 ATC and similar smaller- network options exist with reduced coverage.

For IR-specific use, PilotEdge has been adopted by several flight schools as an ATC-fluency training adjunct; the student files and flies an IFR cross-country in simulation, talks to real human controllers (who are themselves training or recreational), and builds the radio-rhythm and clearance-copy competence that is hard to acquire in the actual aircraft because the actual flight time is expensive. The transfer evidence is practitioner-confidence rather than peer-reviewed, but the application of the W2-001 retrieval- practice finding suggests it should be effective as long as the simulation captures the cognitive load of the radio task realistically.

5.6 WEATHER PRODUCTS

The FAA's `aviationweather.gov` (Aviation Weather Center) is the authoritative free portal. The IR-relevant product suite:

- **METAR and TAF** — terminal observations and forecasts; baseline for go/no-go. - **GFA (Graphical Forecast for Aviation)** — replaced the textual Area Forecast in April 2025 (InFO 25004); the primary en-route forecast tool. - **AIRMET Sierra (IFR/mountain obscuration), Tango (turbulence), Zulu (icing)** — the AIRMET suite for IFR planning. - **SIGMET and Convective SIGMET** — severe weather; convective SIGMETs are the operational hard go/no-go signal for non-FIKI airframes. - **CWA (Center Weather Advisory)** — short-fuse notices from ARTCC meteorologists. - **PIREP** — pilot reports; the only real-time source for in-cloud conditions. - **Skew-T diagrams, prog charts, surface analysis, satellite, radar** — the deeper- diagnostic products. - **Icing forecasts** — the CIP (Current Icing Potential) and FIP (Forecast Icing Potential) products; central to the non-FIKI go/no-go decision.

In-cockpit weather comes through ADS-B FIS-B (free with ADS-B In hardware) or XM/SiriusXM Weather (subscription). FIS-B NEXRAD imagery carries 5–15 minute latency; this latency is the most-discussed pilot-training gotcha in the modern IR cockpit, and the source of "I thought

I was deviating around the cell but I flew into it" accidents. The discipline is *trust but verify with onboard radar or visual contact*.

5.7 PLATE LIBRARIES AND CHART PRODUCTS

The FAA's Terminal Procedures Publication (TPP) contains the approach plates; the IFR Low- and High-Altitude Enroute Charts contain the airway structure. Digital delivery is through ForeFlight or Garmin Pilot. Paper TPPs are still purchasable for those who want a paper backup. The Aeronautical Chart User's Guide is the symbology reference; plate-symbology fluency comes from time with plates plus the Chart User's Guide rather than from any single tutorial.

Jeppesen plates are the alternative to FAA plates; used widely in airline and corporate flying. Jeppesen plate format differs from FAA plate format in several pedagogically meaningful ways (the briefing strip organization, the profile-view conventions); a GA pilot trained on FAA plates needs ~5 hours to fluent up on Jeppesen if they transition.

5.8 CHECKLIST TOOLS

Paper checklists, the airframe-specific POH-derived checklist, the ForeFlight Checklists feature, and the Perspective+/G1000 integrated checklist are the four main options. The working IR pilot's discipline: have a checklist for every phase of flight, use it every flight, do not improvise. The Cirrus checklist integration (the PFD- displayed phase-specific checklist) is the most- integrated implementation; ForeFlight Checklists is the most-portable.

5.9 AI ASSISTANTS

Covered in §III Axis 10. The 2026 modal IR student uses Claude, ChatGPT, or Gemini for ground-school augmentation, regulatory lookup, and oral-exam scenario practice. The Sporty's ChatCFI is the first integrated commercial product in this category. The discipline of verification against authoritative source applies.

5.10 COMPARATIVE TASK TABLE — TOOL STACK BY COMMON IR TASK

The mandate calls for a comparative table of common IR tasks against tool stacks. Below: rows are common IR-pilot tasks; columns are the canonical tool stacks; cells are the idiomatic procedure.

Task	Cirrus Perspective+ + ForeFlight + GFC 700	G1000 NXi + ForeFlight
File IFR flight plan	ForeFlight one-tap from the briefing pack	ForeFlight one-tap
Brief weather	ForeFlight Briefing tool; cross-check on aviationweather.gov	Same
Load and brief approach	Plate from ForeFlight on iPad; load approach in PFD via FMS keypad; brief from PFD plate display	Plate from ForeFlight; loa
Configure for hold	FMS HOLD function; autopilot in GPSS for entry; verify in PFD	Same
Manage missed approach	Activate Missed Approach on FMS; autopilot follows the missed; configure radios	Same
Manage autopilot mode change	Verify mode annunciator on PFD; if unexpected, disconnect with yoke button and hand-fly	Same
Retrieve current weather in flight	FIS-B NEXRAD on PFD/MFD; ForeFlight on iPad; PIREP via ATC	Same
Approach plate during turbulence	Plate displayed on MFD or iPad; briefing strip is mid-plate	Same
LPV approach configuration	Verify LPV minimums armed; APR mode armed; vertical guidance from PFD	Same

The table understates the operational delta. The working IR pilot fluent in the Cirrus Perspective+ stack is operating in a substantially different cognitive environment from the working IR pilot fluent in the steam-gauge + GNS 430W + paper stack; the workload distribution, the failure

modes, the recovery procedures, and the situational-awareness sources are different across the columns. A pilot who trains in one column should not assume IFR competence in another; the type-checkout-style training applies across avionics stacks as much as across airframes.

6

PART V — OUTCOMES, PREREQUISITES, SUCCESSORS

6.1 OUTCOMES MAPPED TO THE COMPETENCE STACK

Layer 1 (Knowledge). The ACS Knowledge Elements across the Areas of Operation — IFR regulations (14 CFR Part 61 Subpart B and Part 91 Subpart B); weather products and IMC meteorology; aerodynamics of instrument flight including unusual-attitude recovery and the spatial-disorientation pathology; navigation systems theory (VOR, GPS, WAAS, RNAV); the approach-plate symbology and the procedural choreography of the ATC system; aircraft systems as they bear on IFR operations (vacuum versus electric instruments, the pitot-static system, deicing/anti-icing, autopilot architecture). Tested by the IRA Knowledge Test (60 multiple-choice, 70% pass) and the oral portion of the Practical Test. The W2-001 evidence base on retrieval practice and spaced repetition applies directly; the IRA question-bank-driven study tradition unintentionally exploits the testing effect.

Layer 2 (Skill). The ACS Skill Elements — basic-attitude instrument flying (full panel and partial panel) to ACS tolerances (typically ±100 ft altitude, ±10° heading, ±10 kts airspeed for normal maneuvers; ¼-scale deflection for ILS and LPV approaches); precision approach (ILS or LPV); non-precision approach (RNAV LNAV, LP, VOR, LOC); circling approach; holding; missed approach; ATC communication including clearance copy and position reporting; partial-panel competence; unusual-attitude recovery by reference to instruments. Tested by the Practical Test flight portion. The deliberate-practice and expertise- development literatures apply; the field's apprenticeship model of CFII-plus-student training maps to W2-004's expertise-adaptive scaffolding.

Layer 3 (Judgment). The ACS Risk Management Elements across every task. Formally tested in the oral and observationally in the flight portion. The IR-specific judgment elements include: go/no- go decision against personal minimums and the 1-2-3 alternate rule (91.169); continuation-bias resistance during deteriorating conditions; alternate-airport selection during planning and re-selection during the flight; decision to declare an emergency, refuse a clearance, or say "unable"; recognition of icing onset and the immediate-action decision tree; convective avoidance under in-cockpit-NEXRAD latency; autopilot mode anomaly response (disconnect, hand- fly, diagnose). Evidence base: the same body SUBJ-003 §III surveyed — accident-data forensics (Boyd & Scharf 2023; Kelly & Efthymiou 2019 on CFIT analysis), the named ADM frameworks, the recognition-primed decision-making tradition (Klein 1989, 1998). The IR-specific layer is under-evaluated empirically.

Layer 4 (Metacognition). Recognition of one's own scan breakdown; recognition of being behind the airplane; recognition that the autopilot is doing something unexpected; recognition that fatigue or hypoxia is degrading performance; calibrated self-assessment of currency and proficiency. The eye-tracking literature (Lounis et al. 2021; Lefrançois et al. 2021; Škvareková & Škultéty 2019; Lü et al. 2020) is the cleanest empirical anchor for scan-as- expertise; the Endsley situational-awareness framework (with the Dekker/Hollnagel folk-model critique) is the dominant theoretical apparatus. The IR-specific Layer-4 development is partial- panel work, hood time under workload, and IPC-equivalent recurrent training.

Layer 5 (Character). The willingness to divert, declare an emergency, refuse a clearance, say "unable," scrub a flight after expense and inconvenience have been committed. The non- testable

layer. The CFII–student relationship is where this develops or fails to develop; psychologically safe environments (W2-009) build the disposition to speak truth about uncertainty; checkride-pressure environments build the disposition to perform certainty. The lab's COMPETENCE-TARGET.md environmental-multiplier finding applies: the IR student trained by a CFII who models the willingness to scrub develops the willingness to scrub; the IR student trained by a CFII who emphasizes "we don't cancel" develops the opposite.

6.2 PREREQUISITES

Nominal (14 CFR 61.65) requirements:

- Hold at least a current Private Pilot Certificate (or be concurrently applying for one) with an airplane, helicopter, or powered-lift rating appropriate to the IR sought. - Read, speak, write, and understand English. - Receive and log ground training from an authorized instructor or a home-study course covering the aeronautical knowledge areas enumerated in 61.65(b). - 50 hours of cross-country PIC time, of which at least 10 must be in airplanes for an IR-Airplane. - 40 hours of actual or simulated instrument time on the areas of operation, of which: - At least 15 hours of instrument flight training from an authorized CFII in the aircraft category for the IR sought. - Up to 20 hours may be in an approved AATD; up to 10 hours may be in an approved BATD (61.65(i)). - One IFR cross-country flight along airways or ATC-directed routing of at least 250 NM with an instrument approach at each airport and three different kinds of approaches with use of navigation systems. - A logbook endorsement from the authorized CFII signifying the applicant is prepared for the IRA Knowledge Test. - Pass the IRA Knowledge Test. - A logbook endorsement from the authorized CFII signifying the applicant is prepared for the Practical Test. - Pass the Practical Test administered by a DPE against FAA-S-ACS-8C.

Actual capability prerequisites (beyond the regulatory nominal): the candidate should have:

- Solid VFR fundamental airmanship (the IR is not the time to repair a wobbly stick-and-rudder baseline; the lab's W2-001 expertise-reversal finding suggests that scaffolding for fundamentals interferes with IR-specific learning if the fundamentals are not robust). - Weather literacy at the working-VFR-pilot level (METAR/TAF/AIRMET/SIGMET; basic synoptic-scale awareness; the seasonal weather patterns of the region the pilot operates in). - Basic-attitude instrument flight capability *before* starting IR training (the 3-hour hood requirement under 61.107(b)(1)(viii) is the legal minimum; in practice a returning pilot benefits from 5–10 hours of hood work under the ifr-for-safety progression before commencing formal IR training). - The maturity to study regulations carefully and the discipline to apply them.

6.3 SUCCESSORS

Commercial Pilot — Airplane Single-Engine Land. The next FAA certificate up. Requires 250 hours total time. Adds the chandelle, lazy eight, eights on pylons, and power-off 180° to landing maneuvers. Substantially overlaps the IR requirements (the 50-hour cross-country and the instrument time count toward Commercial). The CPL + IR combination is the standard floor for professional flying.

Multi-Engine Instrument Rating. A class rating added to the certificate plus the IR for the new class. ~8–12 hours of training typical for the class rating; the IR-for-multi-engine practical test is a modified IRA. Transforms the pilot's understanding of asymmetric thrust and engine-out IFR procedures.

CFII — Certified Flight Instructor — Instrument. The teaching credential. Requires the IR plus the CFI certificate (or the CFII can be added to an existing CFI). The 14 CFR 61.183 requirements include the IR plus 15 hours of PIC time in the aircraft category and class for the CFII sought, plus the FOI and CFII knowledge tests, plus the practical test. Proposed SUBJ-005 candidate in the SUBJ-003 dispatch §I.

Airline Transport Pilot. 1,500 hours minimum with the restricted-ATP exceptions for university-affiliated training programs. The terminal certificate. Out of scope for the PI's GA-not- airlines framing.

Type-specific high-performance IR currency. The Cirrus CSIP-network annual recurrence, the Beechcraft Pilot Proficiency Program (BPPP), the Mooney Owners' Association recurrent programs. Not certificates but type-specific maintenance of working IR competence. The Pilot Proficiency Program for Cirrus (PPP) is the recurrent recertification cycle the type club codifies.

Single-pilot turbine IR. The TBM, Vision Jet, Pilatus PC-12, and King Air pilot communities; type-specific training infrastructures (FlightSafety, CAE, SimCom) provide the recurrent-currency frame. The IR is the floor; the type-specific recurrent training is the maintenance.

The recurrent maintenance regime — IPC and beyond. The Instrument Proficiency Check under 14 CFR 61.57(d) restores currency after a 6- month-beyond-(c) lapse. A serious IPC runs 4–6 hours and exposes the pilot's actual gaps; a nominal IPC is a checkride-shaped exercise that restores legal currency without addressing working-competence drift. The discipline of seeking a serious IPC every 6–12 months, independent of legal currency status, is the field's converged answer to the working- competence-maintenance question.

The IR's assessment apparatus has four layers, parallel to the PPL apparatus SUBJ-003 §VI surveyed.

The IRA Knowledge Test. PSI Services delivers. 60 multiple-choice questions drawn from a public question bank. 70% pass standard. 2.5-hour time limit. The Airman Knowledge Test Report (AKTR) identifies ACS-coded areas the candidate missed; the DPE then probes those areas in the oral. The "everyone studies the question bank" critique is sharper for the IR than for the PPL because the IR is more procedural and the question-bank preparation can substitute for the conceptual understanding more efficiently. The test functions as a credential gate rather than as a diagnostic instrument for Knowledge competence.

The Practical Test — oral plus flight. Administered by a DPE under FAA-S-ACS-8C. The oral probes Knowledge and Risk Management across the Areas of Operation with explicit attention to AKTR-flagged areas. The flight tests the maneuvers, the approaches, the hold, the partial-panel recovery, and the integrated scenario performance against ACS tolerances. Typical DPE fee for the IR practical in central Indiana in 2026: $800–$1,200 (per SUBJ-003 returning-pilot-guide local data; verify for the specific examiner). DPE variability is real and is widely discussed in practitioner forums; the "local-DPE-network effect" — where schools prepare students for the specific DPEs who serve their area — is the IR's version of the same pattern SUBJ-003 surfaced for the PPL.

The Instrument Proficiency Check (IPC) under 14 CFR 61.57(d). Required after instrument currency under 61.57(c) lapses for more than 6 calendar months. Conducted by a CFII, examiner, or Part 121/125/135 check pilot. ACS-shaped. The standardization problem is real (one CFII's IPC versus another's differs more than the ACS nominally permits); the practitioner consensus is that the IPC is the working IR pilot's most important assessment touchpoint and should be treated as a real workout, not a paperwork exercise. The currency-vs-proficiency distinction applies: an IPC that restores legal currency without exposing the pilot's actual gaps is a failure of the IPC's pedagogical function, even if it satisfies the regulatory requirement.

Type-specific recurrent assessment. The Cirrus CSIP-network annual recurrence, the BPPP, the Mooney club programs, and the type-specific simulator-based recurrents (FlightSafety, CAE, SimCom for turbine pilots) constitute a parallel assessment infrastructure. The type-club assessments are not regulatory but are operationally significant — many insurance carriers require type-club recurrent attendance for premium discount or for coverage at all.

Self-assessment instruments. PAVE, IMSAFE, 3P, 5P, the AOPA Air Safety Institute Personal Minimums Worksheet (IR-specific version exists), and the various practitioner-developed pre-flight checklists. Not formally evaluated as assessment instruments; treated as metacognitive scaffolding in the W2-004 sense rather than as cognitive procedures.

A diagnostic battery the agent proposes the working IR pilot could run on themselves biennially. The cheat-sheet codifies the biennial self-audit. Sample diagnostic scenarios: *(a)* You filed IFR for a 1.5-hour flight at noon; during taxi the ATIS reports the ceiling at the destination has dropped to 600 feet and visibility to 1.5 SM with mist. Your destination's published LPV minimum is 250 feet AGL and 3/4 SM; the alternate's LPV minimum is 250/1; the alternate is 80 NM north with a 2,000-foot ceiling and 10 SM visibility. Do you depart? Justify the decision against 91.169 alternate requirements, fuel requirements (91.167), and your personal minimums. *(b)* You are on the ILS at the FAF, 6 miles from the runway, on glide path, 130 knots indicated. The autopilot's flight director command bar suddenly commands a 15° right bank for no apparent reason. You verify NAV mode

is selected and the localizer is alive. What do you do? Justify your immediate action and your subsequent diagnosis. *(c)* You are at the cruise altitude on an IFR flight; the OAT gauge reads −5°C; you notice a trace of rime ice forming on the wing strut. Your airframe is non-FIKI. ATC has you in a hold for sequencing. What do you say to ATC, in what order, and what immediate action do you take? Justify each step.

The diagnostic battery is not a substitute for the IPC. It is a working-IR-pilot self-audit tool that exposes the gap between checkride-recall competence and actual decision competence. The cheat-sheet codifies the framework.

8

PART VII — THE CHEAT SHEET PREVIEW

The lifetime IR cheat sheet (`cheat-sheet.md`) is the durable artifact the rated IR pilot carries forward. It answers two questions — am I legal and competent for this IFR flight, and if not, what do I need to refresh — and serves as both recognition aid and relearning index.

Sections cover the IR-currency calendar (6/6/HIT under 61.57(c) plus the IPC under (d)); the IFR clearance copy structure (CRAFT — Clearance limit, Route, Altitude, Frequency, Transponder); the approach brief format (the practitioner consensus "5T" or "9T" briefing structure with the missed- approach call-out and the alternate verification); the 1-2-3 alternate rule (91.169 — at the destination ETA, if the forecast does not include at least 1 hour before to 1 hour after of at least 2,000 feet ceiling and 3 SM visibility, an alternate is required); the IFR fuel reserve (91.167 — to destination, then to the alternate, then 45 minutes at normal cruise); the missed-approach procedure cadence (Climb, Configure, Communicate, Navigate — the 4 Cs); the required-reports table under 91.183 (Mandatory: time and altitude over designated reporting points in non-radar environment; vacating an assigned altitude; unable to climb/descend at 500 fpm; missed approach; loss of nav, comm, or fix-determination capability; safety of flight reports); the lost-communications procedure under 91.185 (route: assigned, then vector, then expected, then filed; altitude: highest of MEA, expected, or assigned; arrival: descend from EFC if received, otherwise EFC = ETA from the clearance limit); the minimum- equipment quick check; the IR-relevant before-each- flight regulatory currency check (FR, IPC, 6/6/HIT, medical); and a compact glossary of IR-specific acronyms and shorthand.

Hard format target: two to three printable pages, double-sided. The cheat-sheet is for the IR pilot to carry in the front of the logbook or the iPad case and consult before every IFR flight for the first 100 actual-IMC hours, and as needed afterward.

9

PART VIII — WHAT MOSTLY GOES WRONG

The failure modes of U.S. instrument-rated GA pilots, named, characterized, mapped to the competence stack, and matched to partial remediation. Drawn from the AOPA McSpadden Report's annual accident-cluster analysis, NTSB human- factors-themed reports, the IR-specific practitioner literature, and the AOPA Air Safety Institute IR-case-study library.

VFR-into-IMC by the IR-current pilot. The counter-intuitive but recurring pattern: a pilot who holds the rating but is flying VFR exceeds their personal minimums and enters IMC without an IFR clearance, often because they did not file IFR for what was supposed to be a simple VFR trip and did not have a clean recovery to IFR rules when conditions deteriorated. *Layer*: 3 (judgment — pre-flight decision to file IFR) and 5 (character — willingness to deviate from plan). *Partial remediation*: file IFR for any flight where the weather might be marginal; treat the "file IFR vs file VFR" decision as a planning discipline rather than a leisure-time optimization.

Loss of control in IMC. The IR pilot loses control of the airplane in IMC, typically through spatial disorientation, scan breakdown, autopilot failure mismanagement, or fatigue. The 178-second study (Bryan, Stonecipher, and Aron 1954) applies to the non-IR pilot; the IR pilot's loss-of-control-in-IMC mode is closer to 5–10 minutes from onset, and is most often associated with a discrete triggering event (autopilot trim runaway, attitude indicator failure, severe turbulence encounter, unusual attitude during a hand-flown approach). *Layer*: 2 (skill — scan; partial- panel competence; unusual-attitude recovery) and 4 (metacognition — recognition of breakdown). *Partial remediation*: deliberate partial-panel practice every IPC; type-club recurrent unusual-attitude work; the discipline of disconnecting the autopilot at the first sign of unexpected behavior.

Continuation bias into icing. The pilot proceeds through forecast or observed icing conditions because the destination is close, the alternate is far, the AIRMET Zulu was "probably wrong about the freezing level," or some combination. *Layer*: 3 (judgment) and 5 (character). *Partial remediation*: the personal-minimum that says "any forecast icing in my flight altitude block is a no-go for non-FIKI" must be set in advance and enforced regardless of in-flight pressure; the discipline of treating the AIRMET as conservative until the PIREP contradicts it.

Convective penetration of an embedded thunderstorm. The pilot relies on in-cockpit NEXRAD (5–15 minute latency), believes they are flying around the cell, and is in fact flying into it. *Layer*: 1 (knowledge — NEXRAD latency) and 3 (judgment — willingness to deviate further than the radar suggests is necessary). *Partial remediation*: the discipline of treating cell position as direction-and-rate-of-development rather than as fixed; the 20-NM avoidance rule (AIM 7-1-29); the willingness to refuse a vector that takes the airplane closer to a cell than the pilot's minimums allow.

Autopilot mode confusion at the approach gate. The pilot arms NAV mode expecting APR; or arms APR but the autopilot does not capture; or believes the autopilot is in VS but the autopilot has reverted to HDG. *Layer*: 1 (knowledge — mode taxonomy) and 4 (metacognition — recognition that the autopilot's behavior is not what was commanded). *Partial remediation*: AC 90-109A TAA transition training; the discipline of verifying mode annunciator changes by spoken call-out; deliberate hand-flown approach practice every IPC; the Vanderburgh three-levels-of- automation discipline.

Approach-brief skip. The pilot rushes the approach setup, skips or shortens the briefing, and discovers in the descent that the missed- approach procedure was not what they expected, or that the wrong frequency is loaded, or that the LPV minimum was not what they thought. *Layer*: 4

(metacognition — recognition of being behind the airplane and the need to slow down). *Partial remediation*: the discipline of "no approach without a brief" applied universally; the willingness to request "request vectors for delay" from ATC when the brief is not complete.

Fuel mismanagement in IFR. The pilot's flight plan fuel reserve is the 91.167 legal minimum; weather, ATC delay, or holding consumes more than the reserve; the pilot lands with less than 30 minutes (or, in the worst-case category, runs out of fuel in IMC). *Layer*: 3 (judgment) and 4 (metacognition). *Partial remediation*: the personal-minimum "land with 1 hour" discipline; the fuel-totalizer cross-check; the willingness to declare a fuel-state concern to ATC rather than press on.

Lost-comm mishandling. The pilot loses comm in IMC and either applies 91.185 incorrectly or fails to apply it at all. *Layer*: 1 (knowledge — 91.185) and 4 (metacognition — recognition that lost-comm is in fact what is happening, since in-cockpit indications are ambiguous). *Partial remediation*: the cheat-sheet's compact 91.185 summary; recurrent lost-comm scenarios in the IPC.

Currency-not-proficiency drift. The pilot is legally current (61.57(c) 6/6/HIT) but has not actually flown in IMC in 18 months; the 6 approaches were all in clear weather with a safety pilot under the hood. The "I'm IFR current" self- assessment is technically true and operationally misleading. *Layer*: 4 (metacognition — calibrated currency self-assessment) and 5 (character — willingness to honestly name the gap). *Partial remediation*: the IPC every 6–12 months; the type-club recurrent program; the discipline of declining the IFR flight when the honest answer is "I haven't done this in a year."

Returning-IR-pilot decay. The rated IR pilot who has not flown IFR in 2–5 years and who needs substantial re-currency before re-engaging. *Layer*: 4 and 5. *Partial remediation*: a serious IPC with a CFII who knows the pilot's history; a sequence of supervised IMC re-entry flights; the acknowledgment that the rating's prior currency does not transfer across a long lapse.

The pattern across these failure modes mirrors SUBJ-003 §VIII's pattern for primary training: Layer 1 and Layer 2 are well-served by the training apparatus; Layers 3, 4, and 5 — judgment, metacognition, and character — are where the field's failure modes cluster. The IR is one of the cleanest civilian instances of a regulated- competence domain where the upper-layer gap is acknowledged by the field, partially addressed by the recurrent-training apparatus, and not closed by the regulatory floor. The lab's COMPETENCE- TARGET.md framing applies directly: the upper layers are where the lab's distinctive contribution is intended to lie, and the IR is the hardest case civilian training has produced.

10

CLOSING — WHAT GOOD LOOKS LIKE AT SEVERAL STAGES

At the IR checkride. The successful IR candidate demonstrates the ACS Knowledge, Risk Management, and Skill Elements across the Areas of Operation, within the named tolerances, with formal application of PAVE/IMSAFE/3P on every task. They can fly an ILS or LPV approach to ACS minimums, a non-precision approach to ACS minimums, a hold, and a missed approach. They can brief an approach plate. They can handle partial- panel scenarios. They have copied a clearance and demonstrated lost-comm awareness. They have recovered from an unusual attitude by reference to instruments.

At 100 IFR hours. The same pilot has discovered that real IMC workload exceeds the hood; that autopilot mode confusion is silent and dangerous; that ATC in busy airspace moves faster than training prepared them for; that fatigue and dehydration degrade their scan; that their approach-brief discipline slips under stress. They are still alive because they have flown conservatively, refused marginal weather, declared problems early, or been lucky.

At 500 IFR hours. The same pilot has built calibrated go/no-go judgment; honest currency self-assessment; the scan automaticity that permits attention division to non-routine ATC instructions; the willingness to declare an emergency early; the willingness to say "unable." They have built what training did not give them — mostly through deliberate IPC discipline, type- club recurrent training, supervised actual-IMC exposure, and the practitioner-reading habit (Bob Buck, Richard Collins, Wally Roberts).

Returning to IR after a lapse. The challenge is not "rebuild from zero" — it is "rebuild the layers that decay fastest (procedural recall, plate fluency, ATC rhythm, autopilot mode familiarity) while honestly assessing the layers that decay more slowly (weather sense, scan fundamentals, general IFR judgment)." A serious IPC with a CFII who knows the airframe; a sequence of supervised IMC re-entry flights; the acknowledgment that lapsed-currency proficiency is not pre-lapse proficiency.

The PI's profile. Current PPL holder, 150 hours across DA20/DA40/SR20/SR22T, completing the SUBJ-003 returning-pilot-guide's Phase 1 (medical, flight review, 90-day currency) before commencing IR study. The PI's three-year staircase laid out in `pi-ir-curriculum.md`: VFR currency → Stage 1–4 of the ifr-for-safety-guide → IR ground school → IR flight training → IR practical test → post- rating currency and supervised actual-IMC exposure → year-3 target of competent single-pilot IFR in the SR20 for Midwest GA utility.

The Instrument Rating is the floor. The working- IR-pilot competence is what the pilot builds above it. The lab's central observation, applied to this subject: the upper layers of the competence stack are where the work is, where the evidence is thinnest, and where Applied Pedagogy's curriculum work should focus. The IR is unusual among the subjects the lab has investigated because the field knows this — has been working on the upper layers for decades through CRM, SRM, scenario-based training, type-club recurrency, and the AOPA Air Safety Institute case-study apparatus — and has produced a working safety culture that measurably reduces fatal accidents year over year. The honest position, mirroring SUBJ-003's conclusion: aviation has more to teach the lab about training the upper layers of a regulated competence than the lab has to teach aviation. The IR is the sharpest case in the subject for this proposition.

Author's note: the empirical claims in this review were verified against the current FAA edition (eCFR, faa.gov, May 24, 2026) and against the academic literature retrieved via the scholar tool (see `sources.md`). The agent's confidence is highest on FAA citations and lab cross-references, moderate

on practitioner-cited evidence, and lower on specific dollar estimates, schedule estimates, and operator-currency claims. Items marked **`[phone-verify]`** *in the supporting artifacts require the PI's local operator verification before action. The gaps file (*`gaps.md`*) enumerates the verification status of every claim in detail. The cross-references to SUBJ-003 artifacts (*`ifr-for-safety-guide.md`*,* `returning-pilot- guide.md`*,* `review.md` *Parts I–VIII) and to W2-001, W2-004, W2-009, and W2-010 are intended to build on, not duplicate, the lab's prior work.*

REFERENCES

14 CFR Title 14 — eCFR (sections cited new to SUBJ-004) The current Federal Aviation Regulations as relevant to the IR specifically. URL base: `https://www.ecfr.gov/current/title-14/chapter-I`. Most recently verified for cited sections via WebSearch on May 24, 2026 (the eCFR site returned 302-redirects on direct WebFetch attempts; verified via the eCFR public-facing path). Most recent amendment touching 61.65 is **Amdt. 61-157** (November 21, 2024). Sections newly cited or expanded in SUBJ-004 (beyond those already in SUBJ-003 `sources.md`): - 14 CFR 61.65 (Instrument rating requirements) — the IR-specific eligibility, aeronautical experience, knowledge test, and practical test requirements. Subsections: (a) general; (b) aeronautical knowledge; (c) flight proficiency; (d) aeronautical experience for an IR-Airplane; (e) cross-country PIC requirements; (h) aeronautical experience in an aircraft; (i) flight simulator or training device credit. - 14 CFR 61.57(c) (Instrument experience — 6/6/HIT currency requirements). - 14 CFR 61.57(d) (Instrument proficiency check — required after 6 months of 61.57(c) lapse). - 14 CFR 91.167 (Fuel requirements for flight in IFR conditions). - 14 CFR 91.169 (IFR flight plan: Information required; the "1-2-3 rule" for alternate requirements). - 14 CFR 91.175 (Takeoff and landing under IFR; the approach minima, the visibility-required- to-descend rule, the runway-environment items required at DA/DH or MDA). - 14 CFR 91.177 (Minimum altitudes for IFR operations). - 14 CFR 91.183 (IFR communications and required reports). - 14 CFR 91.185 (IFR operations: Two-way radio communications failure — route, altitude, and arrival procedures). - 14 CFR Part 141 Appendix C (the Part 141 IR training curriculum framework with the 35-hour reduced minimum). **Confidence:** High.

1800wxbrief / Leidos Flight Service Already cited in SUBJ-003. **Confidence:** High.

Advisory Circulars - **AC 60-22**, *Aeronautical Decision-Making* (1991). Already cited in SUBJ-003. - **AC 90-105**, *Approval Guidance for RNP Operations and Barometric Vertical Navigation in the U.S. National Airspace System and in Oceanic and Remote Continental Airspace*. The Performance-Based Navigation reference cited in `review.md` §III Axis 9. **Confidence:** High. - **AC 90-107**, *Guidance for Localizer Performance with Vertical Guidance and Localizer Performance Without Vertical Guidance Approach Operations in the U.S. National Airspace System*. The LPV/LP approach reference. **Confidence:** High. - **AC 90-109A**, *Airmen Transition to Experimental or Unfamiliar Airplanes* (2015). The TAA transition training framework. Already cited in SUBJ-003. **Confidence:** High.

Aeronautical Information Manual (AIM) Current: Basic plus Change 1 (effective August 7, 2025) and Change 2 (effective January 22, 2026); the next change is scheduled mid-July 2026 (per SUBJ-003 §I schedule). URL: `https://www.faa.gov/air_traffic/publications/atpubs/aim_html/`. Chapters newly relied on for SUBJ-004: - AIM Chapter 1, Section 2 (Performance-Based Navigation and Area Navigation). - AIM Chapter 5 (Air Traffic Procedures) in full — the operational expectation ATC has of the IR pilot. - AIM 5-4-5 (Instrument Approach Procedures), the LNAV/LP/LPV/LNAV+V taxonomy. - AIM 5-5 (Pilot/Controller Roles and Responsibilities). - AIM 7-1-29 (Thunderstorm avoidance — the 20-NM rule). **Confidence:** High.

Aeronautical Chart User's Guide URL: `https://www.faa.gov/air_traffic/flight_info/aeronav/digital_products/aero_` The plate-symbology reference. Cited in `cheat-sheet.md` §XIV. **Confidence:** High.

AOPA Air Safety Institute IR-Specific Courses URL: `https://www.aopa.org/training-and-safety/air-safety-institute`. Free online courses; case-study-driven; WINGS credit. The *IFR Insights*, *Real Pilot Story*, *Weather Wise*, and *Single Pilot Resource Management* series. **Confidence:** Practitioner-confidence; High for content.

ASA — Instrument Rating Test Prep and Textbook The ASA *Instrument Pilot* textbook (Eckalbar or current author) and ASA test-prep book. URL: `https://asa2fly.com/`. Used widely in Part 141 schools as adjunct. **Confidence:** Practitioner-confidence.

ATP Flight School — Airline Career Pilot Program URL: `https://atpflightschool.com/airline-career-pilot-program/`. 2026 program costs: $123,995 from zero to commercial multi-engine instrument with CFI/CFII; $90,995 starting with a private pilot certificate. 9–11 month program duration. Part 141. Cited in `review.md` §II for context; the airline-pipeline pathway is out of scope for the PI's GA-not-airlines framing. **Confidence:** High.

Aviation Weather Center — aviationweather.gov Already cited in SUBJ-003. Now includes the GFA (Graphical Forecast for Aviation) v2 interface (per InFO 25004, April 2025). **Confidence:** High.

Avidyne IFD Series URL: `https://www.avidyne.com/`. The IFD440/540/550 family of GPS/Nav/Comm units. Cited in `review.md` §IV. **Confidence:** Practitioner-confidence; High for product.

Bjorklund, Alfredson, and Dekker (2006) — Mode Monitoring Eye-Tracking OpenAlex W1989753152. Bjorklund, C. M., Alfredson, J., & Dekker, S. (2006). Mode monitoring and call-outs: An eye-tracking study of two-crew automated flight deck operations. *International Journal of Aviation Psychology*, 16(3), 263–275. **Confidence:** Medium.

Bryan, Stonecipher, and Aron (1954) — *178 Seconds to Live* Already cited in SUBJ-003 `sources.md`. The classic University of Illinois study on non-IR pilots in simulated IMC. **Confidence:** Practitioner-classic.

Buck, Robert N. *Weather Flying.* McGraw-Hill, multiple editions; current edition is the 5th (revised by Robert O. Buck, son of Robert N. Buck). ISBN 978-0-07-179747-1 (5th edition). The canonical practitioner IFR-pilot weather-sense reference. Cited in `review.md` Executive Summary and §V. **Confidence:** Practitioner-classic.

Buck, Robert N. *North Star Over My Shoulder.* Memoir. ISBN 978-0-7432-3741-9. Not curriculum material but shapes the IFR-pilot voice the field calls airmanship. Referenced in `review.md` §V context. **Confidence:** Practitioner-classic.

Cirrus Approach Instrument Rating Program URL: `https://learning.cirrusapproach.com/courses/713/overview`. The type-integrated IR curriculum for pilots training in Cirrus airframes. ~$400. Cirrus Standardized Instructor Pilot (CSIP) network qualification required for the in-airplane portions. Cited in `pi-ir-curriculum.md` §IX. **Confidence:** Practitioner-confidence; High for program existence.

Cirrus CSIP Program URL: `https://cirrusaircraft.com/training/`. CSIP qualification requirements: `https://data.ntsb.gov/Docket/Document/docBLOB?ID=40453073&FileExtension=.PDF&FileName=CSIP+Requ` `Master.PDF`. 3-day standard transition course; instrument-rated transition pathway available. Cited in `pi-ir-curriculum.md` §IV and §IX. **Confidence:** High for the program structure.

Cirrus Owners and Pilots Association (COPA) URL: `https://cirruspilots.org/`. The CAPS Decision-Making Guide already cited in SUBJ-003. The COPA PPP recurrent program cited in `pi-ir-curriculum.md` §X. **Confidence:** Practitioner-confidence.

Collins, Richard L. *Flying IFR.* McGraw-Hill, multiple editions. ISBN 978-0-07-145140-3 (reprint). The practitioner IFR-flying companion to Buck. Cited in `review.md` Executive Summary. **Confidence:** Practitioner-classic.

COMPETENCE-TARGET.md The lab's five-layer competence stack normative document. Cited throughout `review.md` and `cheat-sheet.md`. **Confidence:** High.

FAA WAAS Quick Facts (2024) URL: `https://www.faa.gov/sites/faa.gov/files/WAAS_QFacts_01252024.pdf`. Cited in `review.md` §III Axis 9 for the 4,100+ runway-ends with LPV approaches figure. **Confidence:** High.

FAA-H-8083-15B, *Instrument Flying Handbook* (IFH) Current edition B, originally 2012 with addenda and errata sheets through January 2026. URL: `https://www.faa.gov/sites/faa.gov/files/regulations_policies/handbook` `H-8083-15B.pdf`. The knowledge spine for IR training; covers the national airspace system, the ATC system, human factors, aerodynamics of instrument flight, flight instruments, IFR maneuvers, navigation systems, and emergency operations. **Confidence:** High.

FAA-H-8083-16B, *Instrument Procedures Handbook* (IPH) Current edition B, effective October 2017. The procedural companion to the IFH. URL: `https://www.faa.gov/regulations_policies/handbooks_manuals/aviation/in` **Confidence:** High.

FAA-H-8083-25C, *Pilot's Handbook of Aeronautical Knowledge* (PHAK) 2023. Already cited in SUBJ-003. **Confidence:** High.

FAA-H-8083-28B, *Aviation Weather Handbook* April 13, 2026. Consolidated weather reference. Already cited in SUBJ-003 `sources.md` with the same confidence rating. **Confidence:** High.

FAA-H-8083-2A, *Risk Management Handbook* June 2022. Already cited in SUBJ-003 `sources.md`. **Confidence:** High.

FAA-H-8083-6, *Advanced Avionics Handbook* 2009, first edition with no revision letter. Still the current edition per the FAA Aviation Handbooks index as of May 2026. Content is dated relative to 2026 cockpits (G1000 NXi 2017, GTN 750Xi 2019, Avidyne IFD550 2014, Perspective+ 2017 revision not covered). The IR-specific gap this creates is noted in `review.md` Part II and `gaps.md`. **Confidence:** High that 2009 is the current edition; the content is meaningfully dated.

FAA-H-8083-9B, *Aviation Instructor's Handbook* 2020. Already cited in SUBJ-003. **Confidence:** High.

FAA-S-ACS-8C, *Instrument Rating — Airplane Airman Certification Standards* Current edition C as of 2026; supersedes FAA-S-ACS-8B (which was the edition cited in SUBJ-003 `sources.md`). The testing standard the IR practical test is conducted against. URL: `https://www.faa.gov/training_testing/testing/acs/instrumen` Includes Knowledge, Risk Management, and Skill elements for every task in the Areas of Operation. Companion: FAA-G-ACS-2 Companion Guide for Pilots; FAA-G-ACS-1 Companion Guide for Evaluators. **Confidence:** High.

ForeFlight Already cited in SUBJ-003 §VI. **Confidence:** Practitioner-confidence for usage; High for features.

Garmin Pilot Already cited in SUBJ-003. **Confidence:** Practitioner-confidence.

Garmin GTN 650Xi / 750Xi URL: `https://www.garmin.com/en-US/p/770020`. The current-generation Garmin GA navigator family. Cited in `review.md` §IV. **Confidence:** Practitioner-confidence; High for product.

Garmin GFC 500 and GFC 700 URL: `https://www.garmin.com/en-US/c/aviation/autopilots/`. The current Garmin autopilots. Cited in `review.md` §IV. **Confidence:** Practitioner-confidence; High for product.

Gleim Aviation — Instrument Pilot Kit with Test Prep URL: `https://aviation.gleim.com/shop/ipktso/`. The book-and-software product. 950+ practice questions; FAA test prep online; flight bag. 2026 edition. **Confidence:** Practitioner-confidence; High for product features.

Jeppesen Sanderson — *Instrument/Commercial Manual* URL: `https://www.jeppesen.com/`. ~$200 retail. Standard textbook in Jeppesen-curriculum Part 141 schools. Cited in `review.md` §II. **Confidence:** Practitioner-confidence; High for product.

Joshi, Miller, and Heimdahl (2003) — Mode Confusion Analysis Using Formal Methods OpenAlex W2132177520. Joshi, A., Miller, S., & Heimdahl, M. (2003). Mode confusion analysis of a flight guidance system using formal methods. *22nd Digital Avionics Systems Conference*. DOI: 10.1109/dasc.2003.1245813. Used for the autopilot mode-confusion analysis in `review.md` §IV. **Confidence:** Medium (peer-reviewed conference paper).

Kelly and Efthymiou (2019) — Human Factors in 50 CFIT Accidents OpenAlex W2924170844. Kelly, D., & Efthymiou, M. (2019). An analysis of human factors in fifty controlled flight into terrain aviation accidents from 2007 to 2017. *Journal of Safety Research*. DOI: 10.1016/j.jsr.2019.03.009. Cited in `review.md` §V for CFIT-related judgment evidence. **Confidence:** Medium.

King Schools — Instrument Rating Ground School & Test Prep URL: `https://kingschools.com/instrument-rating-ground-school-test-prep`. $279 standalone. Free lifetime course access; automatic updates; test-pass guarantee. 2024 update added an additional instructor. The classic computer-based pilot-

education product; the conversational Kings style. Cited in `pi-ir-curriculum.md` §V. **Confidence:** Practitioner-confidence for usage and pedagogy; High for current product and price.

Lefrançois, Matton, and Causse (2021) — Eye Gaze Training for Manual Flight Performance OpenAlex W3207385747. Lefrançois, O., Matton, N., & Causse, M. (2021). Improving airline pilots' visual scanning and manual flight performance through training on skilled eye gaze strategies. *Safety*, 7(4), 70. DOI: 10.3390/safety7040070. Cited in `review.md` §III Axis 3 and §V. **Confidence:** High.

Lima Brugnara, de Andrade, Fontes, and Leão (2022) — Safety-II and Aeronautical Decision-Making OpenAlex W4293453102. Lima Brugnara, R., et al. (2022). Safety-II: Building safety capacity and aeronautical decision-making skills to commit better mistakes. *The Aeronautical Journal*. DOI: 10.1017/aer.2022.74. Cited in `review.md` §III. **Confidence:** Medium.

Lounis, Peysakhovich, and Causse (2021) — Visual Scanning Modulated by Pilot Expertise OpenAlex W3129374526. Lounis, C., Peysakhovich, V., & Causse, M. (2021). Visual scanning strategies in the cockpit are modulated by pilots' expertise: A flight simulator study. *PLoS ONE*, 16(2). DOI: 10.1371/journal.pone.0247061. Cited in `review.md` §III Axis 4 and §V for scan as developing expertise. **Confidence:** High.

Lü, Zheng, Wang, and Fu (2020) — ILS Approach Scan Behaviors OpenAlex W3025037941. Lü, Y., Zheng, Y., Wang, Z., & Fu, S. (2020). Pilots' visual scanning behaviors during an instrument landing system approach. *Aerospace Medicine and Human Performance*, 91(11), 857–862. DOI: 10.3357/amhp.5501.2020. Cited in `review.md` §V. **Confidence:** Medium.

Machado, Rod. *Rod Machado's Instrument Pilot's Handbook* (and *Instrument Pilot's Survival Manual*). Already cited in SUBJ-003 §II. **Confidence:** Practitioner-confidence.

Microsoft Flight Simulator (2020, 2024) Already cited in SUBJ-003. **Confidence:** Practitioner-confidence.

Pilot Institute — Instrument Rating Made Easy URL: `https://pilotinstitute.com/course/instrument-rating-made-easy/`. $279 standalone; $349 bundled with Checkride Ace. 320+ video lessons averaging 3 minutes each; 200+ flashcards; 900+ practice questions; test-pass guarantee with $175 cash-back. Cited in `pi-ir-curriculum.md` §V as the agent's recommendation for the PI's profile. **Confidence:** Practitioner-confidence (the practitioner-community reviews are uniformly positive); High for product features and price.

PilotEdge URL: `https://www.pilotedge.net/`. The paid online-ATC simulator network. ~$20–$30/month. Cited in `review.md` §IV. **Confidence:** Practitioner-confidence.

PilotWorkshops IFR Mastery URL: `https://pilotworkshop.com/products/ifr-mastery/`. Subscription $24/month as of 2026. 280+ scenarios. As of May 2026, integrated into the Sporty's Pilot Training app (Sporty's and PilotWorkshops expanded training partnership announcement, May 23, 2026). Counts for FAA WINGS credit. Cited in `review.md` §II and `pi-ir-curriculum.md` §X. **Confidence:** Practitioner-confidence; High for product features and price.

PSI Exams — FAA Knowledge Test contractor For the IRA (Instrument Rating — Airplane) knowledge test. URL: `https://faa.psiexams.com`. 60 multiple- choice, 70% pass standard, 2.5-hour time limit. 2026 fee $175. **Confidence:** High.

Redbird FMX / Frasca Mentor (AATDs) Cited in `review.md` §III and §IV. Redbird URL: `https://simulators.redbirdflight.com` Frasca URL: `https://www.frasca.com/`. **Confidence:** Practitioner-confidence; High for product existence.

Rizvi, Rehman, Cao, and Moncion (2025) — FSTD and AR in GA Pilot Training OpenAlex W4406493335. Rizvi, S. A. Q., Rehman, U., Cao, S., & Moncion, B. (2025). Exploring technology acceptance of flight simulation training devices and augmented reality in general aviation pilot training. *Scientific Reports*. DOI: 10.1038/s41598-025-85448-7. Cited in `review.md` §III Axis 5. **Confidence:** Medium-High (current peer-reviewed).

Roberts, Wally. The "TheCockpit" archive. URL (archive): `http://wallyroberts.com/`. The Wally Roberts column tradition on IFR flying, particularly the "FAR 91.175 and what 'have the runway

environment in sight' actually means" archive. Practitioner- classic in the IR community. **Confidence:** Practitioner-confidence.

Rod Machado — *Rod Machado's Instrument Pilot's Handbook* The prose-forward, pedagogically self-aware textbook. PI's local Dropbox contains the Machado IR Handbook per SUBJ-003 inputs. Cited in `review.md` §II and `pi-ir-curriculum.md` §V. **Confidence:** Practitioner-confidence.

Ryffel et al. (2018) — Eye Tracking for UPRT OpenAlex W2883015976. Ryffel, C. P., Muehlethaler, C. M., Huber, S. M., & Elfering, A. (2018). Eye tracking as a debriefing tool in upset prevention and recovery training (UPRT) for general aviation pilots. *Ergonomics*, 62(2), 319–329. DOI: 10.1080/00140139.2018.1501093. Cited in `review.md` §V for Layer-4 eye-tracking evidence. **Confidence:** Medium.

Sarter, Woods, and Billings (1997) — *Automation Surprises* The canonical Sarter-Woods-Billings paper on automation-induced surprise and mode confusion in airline cockpits. Sarter, N., Woods, D., & Billings, C. (1997). Automation surprises. In G. Salvendy (Ed.), *Handbook of Human Factors & Ergonomics* (2nd ed.). Wiley. **Confidence:** High.

Sarter and Woods (1995) — Mode Confusion in Airline Cockpits Sarter, N. B., & Woods, D. D. (1995). How in the world did we ever get into that mode? Mode error and awareness in supervisory control. *Human Factors*, 37(1), 5–19. **Confidence:** High.

Sheppard Air URL: `https://www.sheppardair.com/`. Question-bank- focused. Particularly popular in the ATP-CTP and airline community; criticized for teaching-to-the- test. Cited in `review.md` §II. **Confidence:** Practitioner-confidence.

Škvareková and Škultéty (2019) — Eye-Tracking During IFR Flights OpenAlex W2965088760. Škvareková, I., & Škultéty, F. (2019). Objective measurement of pilot's attention using eye track technology during IFR flights. *Transportation Research Procedia*. DOI: 10.1016/j.trpro.2019.07.215. The IFR-specific eye-tracking study; cited in `review.md` §III Axis 4 and §V. **Confidence:** Medium.

Sources Already Cited in SUBJ-003 sources.md (cross-referenced) The following sources are cited in SUBJ-004 artifacts but are already fully documented in SUBJ-003 `sources.md` with the same confidence rating: - AOPA Air Safety Institute — Joseph T. Nall Report / Richard G. McSpadden Report (35th McSpadden Report, November 2025, 2023 data). - NTSB Aviation Accident Database. - NTSB/SS-10/01, *Introduction of Glass Cockpit Avionics into Light Aircraft* (2010). - Diehl, A. (1990, 1991). ADM training evaluation. - Buch, D., & Diehl, A. (1984). - Boyd, D., & Scharf, M. (2023). NTSB record analysis. - Sawyer, M., & Shappell, S. (2009). - Helmreich et al. (1999, 2000). TEM. - Klinect et al. (2003). LOSA. - Kearns, S. (2011). Online SRM. - Endsley, M. (1988, 1995, 2000, 2015). SA model. - Dekker, S., & Hollnagel, E. (2004). SA folk-model critique. - Wickens, C. (2002). Multiple-resource theory. - Salas, E., et al. (2001, 2006). CRM meta-analyses. - O'Connor, P., et al. (2008). - Klein, G. (1989, 1998). Naturalistic decision-making. - Orasanu, J., & Connolly, T. (1993). - Craig, P. (2001). *The Killing Zone*. - Knecht, C. (2013). Killing Zone revisited. - Dornan, J., Beckman, W., Gossett, S., & Craig, P. (2007). FITS scenario-based training. - Ayers, F. (2006). FITS-SRM. - Roscoe, S. (1980). Transfer Effectiveness Ratio. - Korteling, J., Helsdingen, A., & Sluimer, R. (2016). MSFS gamers far-transfer only. - Somerville, M., et al. (2025). XR pilot-training meta-analysis.

Sporty's Pilot Shop — Instrument Rating Course URL: `https://www.sportys.com/learn-to-fly/instrument-rating-course.html`. 2026 edition; 13 hours of 4K IFR video filmed in actual IMC by a CFII; 27-maneuver guide; ChatCFI AI assistant integrated. Subscription bundled with the Deluxe Instrument Rating Kit at higher tiers. Cited in `review.md` §II. **Confidence:** Practitioner-confidence; High for product features.

Sporty's Pilot Training App (with PilotWorkshops integration) URL: `https://www.sportys.com/pilot-training-app.html`. The May 2026 integration brought PilotWorkshops VFR Mastery and IFR Mastery into the Sporty's platform. **Confidence:** High for integration; Practitioner- confidence for pedagogy.

SUBJ-001 — Linear Algebra Cited in passing as the prototype subject investigation.

SUBJ-002 — Statistics and Probability Cited in passing as the prototype subject investigation.

SUBJ-003 — Pilot Training (the direct predecessor) `../SUBJ-003-pilot-training/`. The direct predecessor; this investigation builds on SUBJ-003's returning-pilot-guide, ifr-for-safety-guide, review.md (Parts I–VIII), cheat-sheet.md, and sources.md. Cited throughout SUBJ-004 artifacts. **Confidence:** High.

Type-Specific Recurrent Programs - **Beechcraft Pilot Proficiency Program (BPPP)** for Bonanza and Baron line. URL: `https://www.bppp.org/`. **Confidence:** Practitioner-confidence. - **Cirrus Pilot Proficiency Program (PPP)** — COPA-affiliated. 2–3 days immersive recurrent. ~$2,500–$4,000 plus travel. Cited in `pi-ir-curriculum.md` §X. **Confidence:** Practitioner-confidence. - **Mooney Owners' Association recurrent programs.** URL: `https://www.mooneypilots.com/`. **Confidence:** Practitioner-confidence.

Vanderburgh, Warren — "Children of the Magenta" American Airlines Flight Academy, late 1990s. Already cited in SUBJ-003. The canonical practitioner text on automation-dependency failure modes. **Confidence:** Practitioner-classic.

VATSIM URL: `https://vatsim.net/`. Already cited in SUBJ-003. **Confidence:** Practitioner-confidence.

W2-001 — Cognitive Foundations Retrieval practice (d = 0.50–0.70), spacing (d ≈ 0.60), desirable difficulties, transfer, expertise reversal. Cited throughout `review.md`. **Confidence:** High.

W2-004 — Instructional Design Expertise-adaptive scaffolding, worked examples, productive failure. Cited throughout `review.md` §III and §V. **Confidence:** High.

W2-005 — Technology and Learning AI metacognitive-laziness finding. Cited in `review.md` §III Axis 10. **Confidence:** High.

W2-009 — Competence Formation Psychological safety (Edmondson); upper-layer competence development. Cited in `review.md` §I, §III, §V, §VIII. **Confidence:** High.

W2-010 — Training Science Training-pays-for-failure framework. Cited in `review.md` §I. **Confidence:** High.

What-We-Know Snapshot, 2026-05-02 `/Users/guido/Applied Pedagogy/Research Lab/what-we-know/2026-05-02.md`. **Confidence:** High.

White, Padfield, Lu, Advani, and Potter (2021) — Simulator Fidelity for Rotorcraft LOC Training OpenAlex W3196068452. White, M., Padfield, G. D., Lu, L., Advani, S., & Potter, M. (2021). Review of flight simulation fidelity requirements to help reduce 'rotorcraft loss of control in-flight' accident rates. *CEAS Aeronautical Journal*, 12, 773–797. DOI: 10.1007/s13272-021-00542-6. Cited in `review.md` §III Axis 5. **Confidence:** Medium.

X-Plane 12 Laminar Research. Already cited in SUBJ-003. **Confidence:** Practitioner-confidence.

Young, Fanjoy, and Suckow (2006) — Glass Cockpit Impact on Manual Flight Skills OpenAlex W213947652. Young, J. P., Fanjoy, R. O., & Suckow, M. (2006). Impact of glass cockpit experience on manual flight skills. *Journal of Aviation/ Aerospace Education and Research*. DOI: 10.15394/jaaer.2006.1501. The empirical case for the round-gauge-vs-glass primary-training-of-the-scan debate in `review.md` §III Axis 4. **Confidence:** Medium.

Young, Brookhuis, Wickens, and Hancock (2014) — Mental Workload State of Science OpenAlex W2076883103. Young, M. S., Brookhuis, K., Wickens, C. D., & Hancock, P. A. (2014). State of science: Mental workload in ergonomics. *Ergonomics*, 58(1), 1–17. DOI: 10.1080/00140139.2014.956151. Cited in `review.md` §III for Wickens' multiple- resource theory updates. **Confidence:** High.