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Aeronautical Information Manual

(TC AIM)

**COM—COMMUNICATIONS,
NAVIGATION AND SURVEILLANCE**

MARCH 23, 2023

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TRANSPORT CANADA AERONAUTICAL INFORMATION MANUAL (TC AIM)

EXPLANATION OF CHANGES

EFFECTIVE—MARCH 23, 2023

NOTES:

1. Editorial and format changes were made throughout the TC AIM where necessary and those that were deemed insignificant in nature were not included in the “Explanation of Changes.”
2. Effective March 31, 2016, licence differences with ICAO Annex 1 Standards and Recommended Practices, previously located in LRA 1.8 of the TC AIM, have been removed and can now be found in *AIP Canada* GEN 1.7.
3. The blue highlights in the manual represent the changes described in this section.

COM

- (1) [COM 5.2.1 Global Positioning System](#)
This section contains new information and updated locations.
 - (2) [COM 5.2.4 BeiDou Navigation Satellite System](#)
Information was added regarding the current operational status of the satellite system.
 - (3) [COM 5.3.2 Satellite-Based Augmentation System \(SBAS\)](#)
The text in this section was amended for clarity and ease of reading.
 - (4) [COM 5.5.3 Procedures on the Fringe of WAAS Coverage](#)
The title in this section was amended for clarity and new information was added for clarity and ease of reading.
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COM—COMMUNICATIONS, NAVIGATION AND SURVEILLANCE

1.0 VOICE COMMUNICATIONS

1.1 GENERAL

This subpart deals with mobile radio communications between aircraft and ground stations. Particular emphasis is placed on radiotelephony procedures that are intended to promote understanding of messages and reduce communication time.

The primary medium for aeronautical voice communications in Canada is very high frequency–amplitude modulation (VHF-AM) in the frequency range of 118 to 137 MHz. For increased range in northern areas and the North Atlantic, high frequency–single sideband (HF-SSB) is available in the frequency range of 2.8 to 22 MHz.

1.2 REGULATIONS AND GUIDANCE MATERIAL

Operator’s certificates—In accordance with section 33 of the *Radiocommunication Regulations*, a person may operate radio apparatus in the aeronautical service...only where the person holds [a Restricted Operator Certificate with Aeronautical Qualification, issued by Innovation, Science and Economic Development Canada].

Station licences—All radio equipment used in aeronautical services is required to be licensed by Innovation, Science and Economic Development Canada.

For complete information on the requirements for communication in Canada, please consult the *Study Guide for the Restricted Operator Certificate With Aeronautical Qualification (ROC-A)* (RIC-21). To obtain a copy of this study guide, search for “RIC-21” on the Innovation, Science and Economic Development Canada Web site <www.canada.ca/en/innovation-science-economic-development.html>, contact the nearest Innovation, Science and Economic Development Canada district office, or call 1-877-604-7493.

NAV CANADA has published phraseology guides for visual flight rules (VFR), instrument flight rules (IFR), area navigation (RNAV), and ground traffic operations. These guides support standardized pilot-controller-specialist communications and are intended as learning tools and reference guides to phraseology for all pilots flying within Canadian airspace. These guides are available at <<https://www.navcanada.ca/en/aeronautical-information/operational-guides.aspx#d21312acae74bbdbc5cf437abccb139>>.

1.3 LANGUAGE

The use of English and French for aeronautical radio communications in Canada is detailed in *Canadian Aviation Regulations* (CARs) sections 602.133, 602.134, and 602.135. For definitions of terminology and phraseology used in aviation in Canada, refer to the *Glossary for Pilots and Air Traffic Services Personnel* (AC 100-001), which is available on TC’s Web site <<https://tc.canada.ca/en/aviation/reference-centre/advisory-circulars/advisory-circular-ac-no-100-001>>.

1.4 VERY HIGH FREQUENCY (VHF) COMMUNICATION FREQUENCIES—CHANNEL SPACING

The standard very high frequency (VHF) air-ground channel spacing in Canada is 25 kHz. A 760-channel transceiver is necessary for operation of 25-kHz channels. This channel spacing means that some operators with 50-kHz capability will have their access to certain Canadian airspace and airports restricted, as 25-kHz channels are implemented for air traffic control (ATC) purposes. In some areas of Europe, channel spacing has been reduced to 8.33 kHz, which means that the same restrictions may apply.

Because the frequency selectors on some 25-kHz transceivers do not display the third decimal place, misunderstanding may exist in the selection of frequencies. With such transceivers, if the last digit displayed includes two and seven, then the equipment is capable of 25-kHz operations.

Example:

Toronto Centre:..... 132.475 (actual frequency)

ATC Assigned Frequency:..... 132.47 (digit 5 omitted)

Aircraft Radio Display:..... 132.475 or 132.47

In either case, the aircraft radio is actually tuned to the proper frequency.

1.4.1 Remote Communications Outlets (RCOs) and Dial-Up Remote Communications Outlets (DRCOs)

RCOs are VHF transmitters/receivers installed at designated aerodromes to permit communications between aircraft and an FSS or FIC for the provision of FISE or RAAS. An RCO may also be installed at an off-aerodrome location to enhance en route communication coverage for the provision of FISE by FICs.

FISE RCOs use one of the following four frequencies: 123.275, 123.375, 123.475, or 123.55 MHz. At most of these outlets, 126.7 MHz is not active or monitored by a FIC. At these sites, as required, the FIC activates and transmits on 126.7 MHz to provide aeronautical broadcast services (broadcast of SIGMET or urgent PIREP) and to conduct communication searches for overdue aircraft. Further details on the use of RCOs can be found in the General section of the CFS.

A DRCO is a standard RCO with a dial-up unit installed to connect the pilot with an ATS unit (e.g. FIC) via a commercial telephone line. The line is only opened after communication has been initiated by the pilot or ATS. The radio range of the RCO is unaffected by the conversion.

Activation of the system by the pilot is accomplished via the aircraft radio transmitter by keying the microphone button four times with a deliberate and constant action on the published DRCO frequency. Procedures for establishing the link can be found in the General section of the CFS.

See the CFS for more information.

1.4.2 Emergency Frequency 121.5 MHz

Pilots should continuously monitor 121.5 MHz when operating within sparsely settled areas or when operating a Canadian aircraft over water more than 50 NM from shore, unless essential cockpit duties or aircraft electronic equipment limitations do not permit simultaneous monitoring of two VHF frequencies or the pilot is using other VHF frequencies.

Only control towers and FSSs have 121.5 MHz capability, and this emergency frequency is monitored only during these facilities' hours of operation. Remote communication facilities (PAL, RAAS RCO and FISE RCO) do not have 121.5 MHz capability.

During an emergency, a pilot has the following options for communicating with ATS:

- (a) When within radio reception of a control tower or FSS during the facility's hours of operation, call ATS on the tower frequency/FSS MF or 121.5 MHz. It is recommended that pilots use the normal frequency or the frequency in use at the time.
- (b) When within radio reception of a remote communications facility (FISE RCO, RAAS RCO or PAL), call ATS on the published frequency.

NOTE:

FISE RCOs and PALs operate 24 hr/day, while most RAAS RCOs operate part time.

- (c) When out of range for VHF communications (for example at low altitude, along a highway corridor), pilots may use a cell phone if they have cell phone coverage.
- (d) If beyond the radio reception of an ATS facility, or when outside the facility's hours of operation, broadcast on 121.5 MHz or 126.7 MHz, or both, for assistance from other pilots who may be monitoring the frequency.

1.5 VERY HIGH FREQUENCY (VHF) ALLOCATIONS

See *AIP Canada* GEN 3.4.

1.6 USE OF FREQUENCY 5 680 KHZ

See *AIP Canada* (GEN 3.4.

1.7 PHONE USE DURING A RADIO COMMUNICATIONS FAILURE

In the event of an in-flight radio communications failure, and only after normal communications failure procedures have been followed, the pilot-in-command may attempt to contact the appropriate NAV CANADA air traffic service (ATS) unit by means of a conventional cell or satellite phone. Before placing the call, transponder-equipped aircraft should squawk Code 7600.

Public switched telephone network (PSTN) numbers to be used in the event of a communication failure are published in the *Canada Flight Supplement* (CFS).

1.8 CANADIAN BASE OPERATORS (CBO)

See *AIP Canada* GEN 3.4.

1.9 OTHER TELECOMMUNICATION SYSTEM OPERATORS

See *AIP Canada* GEN 3.4.

1.10 SATELLITE VOICE COMMUNICATIONS (SATVOICE)

The aeronautical satellite voice communications (SATVOICE) system uses the public switched telephone network (PSTN) and/or dedicated networks to route calls between aircraft and the appropriate ground party. Dedicated network access switches locate the aircraft anywhere in the world, regardless of the satellite and ground earth station (GES) to which the aircraft is connected.

For ground-to-air calls, the ground party initiates the call using a network access number. Once connected to the network access switch, the ground party provides as a minimum the following information to the appropriate service provider in order to route the call to the aircraft:

- (a) user identification (ID) [Required by Iridium. Inmarsat does not require a user ID, but does require that the telephone number be registered in their system as part of the validation process.];
- (b) personal identification number (PIN);
- (c) priority level; and
- (d) aircraft address in octal format.

In addition to registration, every aircraft is assigned an aircraft address. An aircraft address can be defined in one of three formats: 24-bit format (24 binary characters), hexadecimal format (6 alpha-numeric characters) or octal format (8 characters).

The user ID and/or PIN are given by the service provider when access to the network is granted, and they are used to secure the call.

The priority level may be used by dedicated networks (and the aircraft systems) to end calls of a lower priority, if necessary, and allow incoming calls of a higher priority, although some systems

may establish a 3-way call, so that the higher priority call can interrupt the ongoing conversation without ending it. In that case, the pilot can hear both ground parties at the same time and determine which is more important.

Table 1.1—Priority Levels for Satellite Voice Communications

| Priority level | Use | Examples |
|---|---|---|
| 1/EMG/Q15 Emergency Safety of Flight | Distress and urgency | Rapid descent Urgent weather deviation |
| 2/HGH/Q12 Operational High Safety of Flight | Flight safety | Altitude request |
| 3/LOW/Q10 Operational Low Safety of Flight | Regularity of flight, meteorological, administrative. Typically assigned to calls between aircraft operators and their aircraft | Flight information service Dispatch Maintenance |
| 4/PUB/Q9 Non-operational Non-safety | Public correspondence | Public phone calls |

Flight crews should only act on an air traffic control (ATC) clearance or instruction from a SATVOICE call with priority level 2. (Priority level 1/EMG/Q15 is reserved for outbound calls from aircraft.)

For air-to-ground calls, a telephone numbering plan has been developed that assigns short codes, as well as PSTN numbers, specific to each flight information region (FIR). When a GES receives the unique short code from the aircraft via satellite, it is converted and the call is routed to the appropriate air traffic services (ATS) unit.

Prior to using SATVOICE equipment for priority level 1, 2 or 3 calls, the aircraft operator should address flight crew training and qualification, maintenance, minimum equipment list (MEL), user modifiable software and service agreements with the commercial service provider. Installations would normally be approved by the state of registry or state of the operator, in accordance with Federal Aviation Administration (FAA) Advisory Circular (AC) 20-150A (or equivalent).

When using SATVOICE, pilots should apply the radiotelephony conventions and phraseology used for VHF/HF communications.

Operational procedures, along with SATVOICE short codes and PSTN numbers for aeronautical stations, are published in *AIP Canada* GEN 3.4, and on en route low altitude and en route high altitude charts.

2.0 LOCATION INDICATORS

Responsibility for Canadian location indicators rests with the Aeronautical Information Services Division of NAV CANADA. Location indicators are listed in the *Canada Flight Supplement* (CFS) and *Canada Water Aerodrome Supplement* (CWAS).

3.0 DATA LINK COMMUNICATION

3.1 DATA LINK APPLICATIONS

The generic term “data link” encompasses different types of applications that can transfer data to and from an aircraft. In Canada, data link applications used by air traffic service (ATS) include data link automatic terminal information service (D-ATIS), pre-departure clearance (PDC) via the airline host, departure clearance (DCL), oceanic clearance (OCL), automatic dependent surveillance waypoint position reporting (ADS WPR) and controller-pilot data link communications (CPDLC). Operational information regarding Canadian applications can be found in *AIP Canada* GEN 3.4.

3.2 AIRCRAFT COMMUNICATIONS ADDRESSING AND REPORTING SYSTEM (ACARS) AND FUTURE AIR NAVIGATION SYSTEMS (FANS) 1/A

Many aircraft data link applications transfer data using the aircraft communications addressing and reporting system (ACARS). In the early 1990s, air traffic control (ATC) units in the United States began to use ACARS-based pre-departure clearance (PDC) applications to alleviate the problem of congestion on clearance delivery frequencies.

Seeing the benefits of this early type of application, airlines began to push for additional air traffic service (ATS) data link applications. Notwithstanding the reduced performance of ACARS networks that existed at the time, using ACARS-based applications was a valuable step towards early introduction of future air navigation systems (FANS). Based on this, various ATS applications operating on the ACARS network were developed. The original Boeing version of these applications was known as FANS 1, whereas the Airbus version was termed FANS A. Today, new FANS applications such as FANS 1/A+ and FANS B continue to be used in airspace not suited for traditional surveillance coverage.

3.3 AERONAUTICAL TELECOMMUNICATIONS NETWORK (ATN)

As reliance on data link increased, a new aeronautical telecommunications network (ATN) was implemented to enable greater data link performance. Compared to the original aircraft communications addressing and reporting system (ACARS) network, the new ATN uses well-defined protocols, specifically designed to provide reliable communications service over dissimilar networks. Aircraft equipped for both ATN and future air navigation system (FANS) applications are said to be equipped with “dual-stack”.

3.4 DATA LINK SERVICE PROVIDERS

To operate data link, it is necessary to have a contract with at least one data link service provider. Major service providers include Rockwell Collins (formerly ARINC) and Société Internationale de Télécommunications Aéronautiques (SITA). These companies provide a variety of air-ground data links, operating in different frequency bands to ensure global coverage.

3.5 DATA LINK NETWORKS

Traditionally, analog very high frequency (VHF) was the most commonly used medium to transmit aircraft communications addressing and reporting system (ACARS) messages. This medium of ACARS transmission is known as plain old ACARS (POA). The low-speed characteristics of a POA data link require a number of frequencies to fully service all users. For example, almost a dozen VHF frequencies are required in North America in order to provide a reliable service. As the number of analog VHF data link transmissions continues to increase across busy areas, available channels in the aeronautical VHF band are approaching saturation.

New high speed digital data link systems transmitting in the VHF range are known as VHF digital link (VDL). Different forms of VDL (Mode 1 through 4) have been defined. This new digital architecture is called ACARS Over AVLC (AOA), where the term AVLC refers to aviation VHF link control, which is the protocol used over the VHF link for the relatively common VDL Mode 2 system.

To access VDL service, aircraft must be fitted with a communications management unit (CMU) that is equipped with a digital connection to a VHF data radio (VDR) transceiver. The CMU processes all the ACARS applications and can be upgraded to integrate both VDL and ATN functionality. The CMU automatically switches between AOA and POA according to service availability.

While VDL may provide faster message response times (two to eight seconds) than analog VHF, the system is still limited to line-of-sight coverage. When beyond line-of-sight of a VDL ground station, some aircraft may also have the capability for HF data link (HFDL) and/or communications through satellite data link (SATCOM).

Satellite data links provide greater coverage, although except for Iridium they are limited in the polar regions since most of the satellites are stationary over the equator. Satellite data links are also slower than VHF in response time (12–25 s). Service providers with near-global coverage include Inmarsat (geostationary earth orbit [GEO] satellites) and Iridium (low earth orbit [LEO] satellites in polar orbits for worldwide coverage); others provide coverage in particular regions, such as the multifunctional transport satellite (MTSAT) over the Pacific Ocean.

HFDL provides near global coverage including over the polar regions, but message transit times (approximately 80 s) are much lengthier than other mediums.

3.6 AIRCRAFT COMMUNICATIONS ADDRESSING AND REPORTING SYSTEM (ACARS) INITIALIZATION

The core of the airborne data link system is called the aircraft communications addressing and reporting system (ACARS) management unit (MU) or communications management unit (CMU). At the initiation of a flight, one of the first flight crew actions is to perform the ACARS system initialization. This INIT REQUEST establishes a link with the airline ground system, and informs it that the aircraft is being prepared for departure.

3.7 DATA LINK AUTOMATIC TERMINAL INFORMATION SERVICE (D-ATIS)

Data link automatic terminal information service (D-ATIS) enables delivery to the cockpit of automatic terminal information service (ATIS) information in text format via data link. This results in a reduction of flight crew workload, eliminating the need to listen to the ATIS broadcast and hand transcribe the message during busy periods. Thanks to data link service provider coverage areas, D-ATIS can also be accessed well in advance of descent and approach. Flight crew flying aircraft communications addressing and reporting system (ACARS) equipped aircraft can send ATIS requests and receive ATIS information using their multipurpose control and display unit (MCDU).

D-ATIS implementation can vary in both avionics and ground systems. In Canada, D-ATIS is available on the Rockwell Collins (formerly ARINC) air traffic service (ATS) server.

3.8 PRE-DEPARTURE CLEARANCE (PDC)

Pre-departure clearance (PDC) via the airline host is a system that provides instrument flight rules (IFR) departure clearances (DCL) via data link to subscribing airlines at selected airports. The PDC message is sent from the tower to an airline's server. The airline then takes responsibility for delivery of the PDC via either the aircraft communications addressing and reporting system (ACARS) data link or, for non-ACARS-equipped aircraft, through some other means such as a gate printer.

Instead of a verbal readback of the entire clearance, air traffic control (ATC) primarily requires readback of the flight plan unique identifier (FPUI). This is a four-character (three numeric and one alphabetic) code included in the PDC message. See *AIP Canada* GEN 3.4 for a list of airports offering PDC service along with registration instructions.

3.9 DEPARTURE CLEARANCE (DCL)

Another data link application similar to pre-departure clearance (PDC) is called DCL, which stands for departure clearance. The DCL message itself may contain the abbreviation PDC, however the delivery method is different for the DCL application. In DCL, the data link dialog is directly between the flight crew and the controller. The flight crew initiates DCL by sending a departure clearance request (RCD). That RCD is routed to the tower, where the controller can send the clearance to the aircraft directly via data link. When sending a RCD, the flight crew will immediately receive the following flight system message (FSM): RCD RECEIVED – REQUEST BEING PROCESSED – STANDBY.

If the RCD cannot be correlated to the flight plan or if the RCD was sent too late, the flight crew may receive one of the following FSMs: RCD REJECTED – FLIGHT PLAN NOT HELD – REVERT TO VOICE PROCEDURES or RCD REJECTED – ERROR IN MESSAGE – REVERT TO VOICE PROCEDURES – RCD TOO LATE.

When air traffic control (ATC) receives a valid RCD, it will respond by sending the departure clearance message (CLD) and, in turn, the flight crew will respond with a departure clearance readback (CDA). Upon successful reception of a matching CDA, the flight crew will receive a FSM that states: CDA RECEIVED – CLEARANCE CONFIRMED.

At any time during the clearance process, if the flight crew receives a FSM stating to REVERT TO VOICE, the data link clearance becomes void and the flight crew should contact ATC.

Other examples of FSM error messages include:

- (a) RCD REJECTED – REQUEST ALREADY RECEIVED – STANDBY
- (b) RCD REJECTED – ERROR IN MESSAGE – REVERT TO VOICE PROCEDURES
- (c) CDA REJECTED – CLEARANCE CANCELLED – REVERT TO VOICE PROCEDURES

Unlike PDC, there is no registration requirement to use DCL; however, operators must be Rockwell Collins (formerly ARINC) or Société Internationale de Télécommunications Aéronautiques (SITA) data link subscribers. A list of airports offering DCL service can be found in *AIP Canada* GEN 3.4.

3.10 AUTOMATIC DEPENDENT SURVEILLANCE CONTRACT (ADS-C)

Position reporting is required in oceanic and remote airspace where there is no other means of surveillance. Automatic dependent surveillance - contract (ADS-C) waypoint position reporting (WPR) via data link can overcome issues with voice reporting. Automatic dependent surveillance (ADS) is a surveillance technique for use by air traffic services (ATS) in which aircraft automatically provide, via data link, information derived from on-board position-fixing and navigation systems. ADS allows controllers to obtain position data from future air navigation system (FANS) equipped aircraft in a timely manner, thereby facilitating route conformance monitoring in non-surveillance airspace.

An ADS-C is initiated by the ATS facility and it identifies the types of information and the conditions under which reports are to be sent by the aircraft. Some types of information are included in every report, while other types are provided only if specified in the ADS-C request. There are three types of ADS-C:

- (a) periodic (a time interval at which the aircraft system sends an ADS-C report),
- (b) demand (a single ADS-C periodic report), and
- (c) event (triggered by a particular event such as a waypoint change event).

ADS-C are managed by ATS facilities based on their surveillance requirements, and ADS reports are sent automatically without notification to, or action required by, the flight crew. In the event that an ADS report is not received, air traffic control (ATC) would attempt to contact the flight crew to obtain the position report via voice. In the event of ADS service interruptions, aircraft equipment failures or loss of signal coverage, flight crews are expected to resume voice reporting. Flight crews should be aware of the limitations associated with available aircraft equipment and the signal coverage over the intended route.

Operational procedures for automatic dependent surveillance waypoint position reporting (ADS WPR) can be found in *AIP Canada* GEN 3.4.

3.11 CONTROLLER-PILOT DATA LINK COMMUNICATIONS (CPDLC)

Controller-pilot data link communications (CPDLC) is a data link application that supports the exchange of text-based messages between a controller and the flight crew. Text messages provide greater clarity than spoken very high frequency (VHF) or high frequency (HF) radio communications, so the risk of error is significantly decreased. Other advantages associated with CPDLC include:

- (a) reducing voice channel congestion in busy airspace;
- (b) providing direct controller-pilot communications (DCPC) in airspace where it was not previously available on voice channels;
- (c) facilitating air traffic control (ATC) communications with flight crews whose first language is not English;

- (d) reducing flight crew input errors, by allowing the loading of information from specific uplink messages into other aircraft systems, such as the flight management system (FMS) or aircraft radios;
 - (e) allowing the flight crew to request complex route clearances, which the controller can respond to without having to manually enter a long string of coordinates;
 - (f) reducing flight crew workload by supporting automatically transmitted reports when a specific event occurs, such as reaching the new flight level on an altitude change clearance; and
 - (g) reducing controller workload by providing automatic flight plan updates when specific downlink messages (and responses to some uplink messages) are received.
- (c) the aircraft registration and/or aircraft address (as entered in Item 18, preceded by REG and/or CODE, of the ICAO flight plan); and
 - (d) the departure and destination aerodromes, when required (as entered in Items 13 and 16 of the ICAO flight plan).

Canadian ATS facility identifiers can be found in *AIP Canada* GEN 3.4.

3.13 CURRENT/NEXT DATA AUTHORITIES

Aircraft can display two controller-pilot data link communications (CPDLC) air traffic service (ATS) facility connections at any time, but only one can be active. The ATS facility with which an aircraft has an active connection is the current data authority, sometimes displayed to the flight crew as CURRENT ATC. The ATS facility with the inactive connection is referred to as the next data authority. Under normal circumstances, the current data authority will initiate a transfer to an adjacent data link-capable ATS facility when the aircraft approaches the appropriate boundary. These transfers are normally automatic and no flight crew action is required.

CPDLC messages consist of a set of message elements, most of which correspond to radiotelephone phraseology. CPDLC message elements that are sent to an aircraft are referred to as uplink messages, or UM, whereas message elements that are sent by the aircraft are downlink messages, or DM. There are two types of CPDLC implementations: future air navigation systems (FANS) 1/A and aeronautical telecommunications network (ATN) based CPDLC.

Operational procedures for CPDLC can be found in *AIP Canada* GEN 3.4 and ENR 7.5.5 for use of CPDLC in the ICAO NAT Region.

3.12 AIR TRAFFIC SERVICES FACILITIES NOTIFICATION (AFN)

The first step for automatic dependent surveillance (ADS) or controller-pilot data link communications (CPDLC) is the air traffic services facilities notification (AFN), sometimes known as the air traffic control (ATC) logon process; it is typically initiated by the flight crew. The purpose of the AFN is to provide air traffic service (ATS) with the data link applications supported by the aircraft system and the unique identification of the aircraft. This allows ATS to correlate the logon information with the flight plan on file, ensure that messages are sent to the correct aircraft, and make certain that any subsequent reports and/or messages update the correct flight plan. This exchange of data link context is needed prior to any CPDLC or ADS connection.

An AFN is needed when the aircraft does not already have a connection, such as when the aircraft is preparing for departure, or when the aircraft is planning to enter an area where ADS and CPDLC services are available after transiting an area where those services were not available.

To perform an initial logon request, the flight crew enters into the data link equipment:

- (a) the four-character International Civil Aviation Organization (ICAO) facility identifier for the ATS unit that the logon request will be sent to;
- (b) the aircraft identification (as entered in Item 7 of the ICAO flight plan);

4.0 GROUND-BASED RADIO NAVIGATION AIDS

4.1 GENERAL

Ground-based radio navigation systems available for use in Canada include: distance measuring equipment (DME), instrument landing system (ILS), localizer (LOC), non-directional beacon (NDB), precision approach radar (PAR), tactical air navigation aid (TACAN), VHF omnidirectional range (VOR), and a combination of VOR and TACAN (VORTAC).

4.2 ACCURACY, AVAILABILITY AND INTEGRITY OF GROUND-BASED NAVIGATION AIDS

Aviation navigation systems must meet stringent accuracy, availability and integrity requirements as specified in the International Civil Aviation Organization's (ICAO) Annex 10.

Measures to improve availability include:

- (a) *Electronic means*—The provision of alternate or redundant circuitry for the electronic elements of the navigation aid (NAVAID).
- (b) *Emergency back-up power*—All instrument landing system (ILS) and VHF omnidirectional range (VOR) facilities for which NAV CANADA has responsibility, as well as distance measuring equipment (DME) and tactical air navigation aid (TACAN) associated with these facilities, are provided with emergency power. Additionally, many non-directional beacons (NDBs) are provided with emergency power.

Measures to maintain accuracy and integrity of the navigation signals include:

- (a) *Executive monitoring*—An electronic means in which the system checks its critical parameters. In the event of an out-of-tolerance condition, it either changes to an auxiliary back-up equipment or shuts the system down if there is no redundancy or if the redundant circuit has also failed. This monitoring is continuous.
- (b) *Periodic maintenance*—NAVAIDs are periodically tested by qualified technologists.
- (c) *Flight inspection*—In-flight inspections of ILS, VOR and DME are carried out by specially equipped aircraft on a regular basis to ensure that standards are met.

During periods of routine or emergency maintenance, or when a NAVAID is identified as not meeting the required performance standard, it is temporarily removed from service and a NOTAM is issued to advise pilots of the deficiency. The removal of the transmitted NAVAID identification can also warn pilots that the facility may be unreliable even though it may still transmit a navigation signal. Under these circumstances the facility should not be used. Similarly, prior to commissioning, a new facility (particularly VOR or ILS) may transmit with or without identification. In such cases, a NOTAM would identify that the facility is unavailable and not to be used for navigation.

The end result of these combined efforts is a safe and reliable air navigation system which meets the established standards. Nevertheless, prior to using any NAVAID, pilots should do the following:

- (a) Check NOTAMs prior to flight for information on NAVAID outages. These may include scheduled outages for maintenance or calibration. For remote aerodromes, or aerodromes with community aerodrome radio station (CARS), it is recommended that pilots contact the CARS observer-communicator (O/C) or the aerodrome operator prior to flight to determine the condition of the aerodrome, availability of services and the status of NAVAIDs.
- (b) Ensure that on-board navigation receivers are properly tuned and that the NAVAID identifier is aurally confirmed.
- (c) Visually confirm that the appropriate indicator displays are presented.

4.3 PILOT REPORTING OF ABNORMAL OPERATION OF GROUND-BASED NAVIGATION AIDS (NAVAIDS)

Pilots are responsible for reporting any navigation aid (NAVAID) failure or abnormality to the appropriate air traffic service (ATS) facility. If it is not practical to report while airborne, a report should be filed after landing.

Reports should contain the nature of the abnormal operation detected by the pilot and the approximate magnitude and direction of any course shift (if applicable). The magnitude may be either in miles or degrees from the published bearing. Reports should also include the approximate distance of the aircraft from

the NAVAID when the observation was made and the time and date of the observation.

4.4 INTERFERENCE WITH AIRCRAFT NAVIGATIONAL EQUIPMENT

Some portable electronic devices can interfere with aircraft communications and radio navigation systems. The radiation produced by frequency modulation (FM) radio receivers and television broadcast receivers falls within the instrument landing system (ILS) localizer (LOC) and VHF omnidirectional range (VOR) frequency band, while the radiation produced by amplitude modulation (AM) radio receivers falls within the frequency range of automatic direction finder (ADF) receivers. This radiation could interfere with the correct operation of ILS, VOR and ADF equipment. Pilots are therefore cautioned against permitting the operation of any portable electronic device on board their aircraft during takeoff, approach and landing.

After extensive testing, Industry Canada has concluded that the switching on or use of handheld electronic calculators can cause interference to airborne ADF equipment in the 200 to 450 kHz frequency range when the calculator is held or positioned within 5 ft of the loop or sense antenna, or lead-in cable installation of the system. Pilots, especially of small aircraft and helicopters, are therefore cautioned against allowing the operation of calculators on board their aircraft while airborne.

4.5 VHF OMNIDIRECTIONAL RANGE (VOR)

The VHF omnidirectional range (VOR) is a ground-based, short-distance navigation aid (NAVAID) which provides continuous azimuth information in the form of 360 usable radials to or from a station. It is the basis for the very high frequency (VHF) airway structure. It is also used for VOR non-precision instrument approaches.

Frequency band—VORs in Canada operate on assigned channels spaced at 0.05 MHz (50 kHz) increments within the frequency range 112.0 to 117.95 MHz.

The implication for users is that, in airspace serviced solely by VOR, aircraft equipped with older VOR receivers which cannot be tuned to two decimal places (e.g. 115.25 MHz) may not be able to operate under instrument flight rules (IFR). Of course, area navigation (RNAV), where approved for use, may enable operation under IFR.

Receivers with integrated distance measuring equipment (DME) (i.e. VOR/DME receivers) normally select the associated DME “Y” channel automatically, while stand-alone DME receivers display the “X” and “Y” channels separately.

Range—VOR reception is subject to line-of-sight restrictions and range varies with aircraft altitude. Subject to shadow effect, reception at an altitude of 1 500 ft above ground level (AGL) is about 50 NM. Aircraft operating above 30 000 ft normally receive VOR at a distance of 150 NM or more.

Identification—Identification is accomplished by means of a three-letter location indicator keyed in Morse code at regular intervals.

VOR courses—Theoretically, an infinite number of courses (radials) are radiated from a VOR station; however, in actual practice, 360 radials are usable under optimum conditions.

The accuracy of course alignment for published VOR radials is $\pm 3^\circ$. Unpublished radials are not required to meet a particular standard of accuracy and may be affected by siting difficulties. Any significant anomalies in published radials sent out from VOR serving an aerodrome will be published in the *Canada Flight Supplement* (CFS).

4.5.1 VHF Omnidirectional Range (VOR) Receiver Checks

Where RNAV routes have not been published, VOR remains the primary NAVAID for use in Canada. It is important that the accuracy of the aircraft equipment be checked in accordance with principles of good airmanship and aviation safety.

While standard avionics maintenance practices are used for checking aircraft VOR receivers, dual VOR equipment may be checked by tuning both sets to the same VOR facility and noting the indicated bearings sent to that station. A difference greater than 4° between the aircraft's two VOR receivers indicates that one of the aircraft's receivers may be beyond acceptable tolerance. In such circumstances, the cause of the error should be investigated and, if necessary, corrected before the equipment is used for an IFR flight.

4.5.2 Airborne VHF Omnidirectional Range (VOR) Check

Aircraft VOR equipment may also be checked while airborne by flying over a landmark located on a published radial and noting the indicated radial. Equipment which varies more than $\pm 6^\circ$ from the published radial should not be used for IFR navigation.

4.6 NON-DIRECTIONAL BEACON (NDB)

Non-directional beacons (NDBs) combine a transmitter with an antenna system providing a non-directional radiation pattern within the low frequency (LF) and medium frequency (MF) bands of 190–415 kHz and 510–535 kHz. NDBs are the basis of the LF/MF airway and air route system. In addition, they function as marker beacons for instrument landing system (ILS) as well as non-precision approach (NPA) aids for NDB instrument approaches.

- (a) *Identification*—Identification consists of two or three letter or number indicators keyed in Morse code at regular intervals. (Private NDBs consist of a letter/number combination.)
- (b) *Classification*—NDBs are classified by high, medium or low power output as follows:
 - (i) “H” power output is 2 000 W or more;
 - (ii) “M” power output is from 50 W to less than 2 000 W; and
 - (iii) “L” power output is less than 50 W.

- (c) *Accuracy*—NDB systems are flight checked to an accuracy of at least $\pm 5^\circ$ for an approach and $\pm 10^\circ$ for en route. However, much larger errors are possible due to propagation disturbances caused by sunrise or sunset, reflected signals from high terrain, refraction of signals crossing shorelines at less than 30° and electrical storms.

4.7 DISTANCE MEASURING EQUIPMENT (DME)

Distance measuring equipment (DME) functions by means of two-way transmissions of signals between the aircraft and the DME site. Paired pulses at a specific spacing are sent out from the aircraft and are received by the ground station. The ground station then transmits paired pulses back to the aircraft on a different frequency. The time required for this signal exchange is measured in the airborne DME unit and is translated into distance (nautical mile [NM]) from the aircraft to the ground station. Distance information received from DME is slant range distance and not actual horizontal distance. Accuracy of the DME system is within ± 0.5 NM or three percent of the distance, whichever is greater.

DME is collocated with most Canadian VHF omnidirectional range (VOR) installations (VOR/DME) and with many instrument landing system (ILS) and localizers (LOCs). In some cases, DME are also collocated with non-directional beacons (NDBs) to provide improved navigation capability. For collocated sites, a single keyer is used to key both the VOR/ILS/LOC and the DME with the three-letter location indicator. The VOR/ILS/LOC transmits three consecutive indicator codes in a medium pitch of 1 020 Hz followed by a single DME indicator code transmitted on the DME frequency (ultrahigh frequency [UHF]) and modulated at a slightly higher pitch of 1 350 Hz. In the event that synchronization from the VOR/ILS/LOC should fail, the DME identification will be transmitted independently.

The DME system is in the UHF band and therefore is limited to line-of-sight reception with a range similar to that of a VOR. Most DME “X” and “Y” channels are paired with VOR and LOC frequencies. As a result, the receiving equipment in most aircraft provide automatic DME selection through a coupled VOR/ILS receiver. Otherwise, the DME interrogator must be selected to the paired VOR or LOC frequency. Distance information from an independent tactical air navigation aid (TACAN) facility can be obtained by selecting the appropriate paired VOR frequency. (In that case, only DME information is being received; any apparent radial information must be ignored.) The DME paired frequency and channel number are published in the *Canada Flight Supplement* (CFS) and on instrument flight rules (IFR) en route charts in the navigation data box for all TACAN and DME installations.

By convention, those frequencies requiring only one decimal place (e.g. 110.3 MHz) are known as “X” channels and those associated with two decimal places are designated as “Y” channels (e.g. 112.45 MHz).

4.8 TACTICAL AIR NAVIGATION (TACAN)

Tactical air navigation aid (TACAN) is a navigation aid (NAVAID) used primarily by the military for en route, non-precision approaches (NPAs) and other military applications. It provides azimuth in the form of radials and slant distance in nautical miles (NM) from the ground station. The system operates in the ultrahigh frequency (UHF) range with the frequencies identified by channel number. There are 126 channels.

TACAN users may obtain distance information from a distance measuring equipment (DME) installation by selecting the TACAN channel that is paired with the VHF omnidirectional range (VOR) frequency. This TACAN paired channel number is published in the *Canada Flight Supplement* (CFS) for every VOR/DME facility.

CAUTION:

Only DME information is being received by the TACAN avionics. Any apparent radial information obtained through the TACAN avionics from a VOR/DME facility can only be false signals.

4.9 VHF OMNIDIRECTIONAL RANGE AND TACTICAL AIR NAVIGATION AID (VORTAC)

A number of tactical air navigation aids (TACANs), supplied by the Department of National Defence (DND), are collocated with VHF omnidirectional ranges (VORs) to form facilities called VORTACs.

This facility provides VOR azimuth, TACAN azimuth and slant distance from the site. Components of a VORTAC operate simultaneously on paired frequencies so that aircraft distance measuring equipment (DME) avionics, when tuned using the paired VOR frequency, will obtain distance information from the DME component of the TACAN. An aircraft must be equipped with a VOR receiver to use VOR, appropriate equipment to use DME, or TACAN equipment to use TACAN (azimuth and DME).

4.10 INSTRUMENT LANDING SYSTEM (ILS)

The instrument landing system (ILS) is designed to provide an aircraft with a precision final approach with horizontal and vertical guidance to the runway. The ground equipment consists of a localizer (LOC), a glide path transmitter, a non-directional beacon (NDB), and a distance measuring equipment (DME) fix or an area navigation (RNAV) fix to denote the final approach fix (FAF). See Figure 4.1 for a typical ILS installation.

4.10.1 Localizer (LOC)

The LOC provides the pilot with course guidance to the runway centreline. When the LOC is used with the glide slope, it is called an ILS. The LOC is adjusted to provide an angular width typically between 3° and 6°, depending on runway length. The transmitter antenna array is located at the far end of the runway away from

the approach. LOCs operate in the 108.1–111.9 MHz frequency range. The LOC may be offset up to 3° from the runway heading and still publish as a straight-in procedure; however, the amount of offset will be published as a note on the approach plate. LOC alignment exceeding 3° of the runway heading will have an “X” as the first letter of the indicator, whereas LOCs and back courses with an alignment of 3° or less will have an “I” as the first letter.

The normal, reliable coverage of ILS LOCs is 18 NM within 10° of either side of the course centreline and 10 NM within 35° of the course centreline.

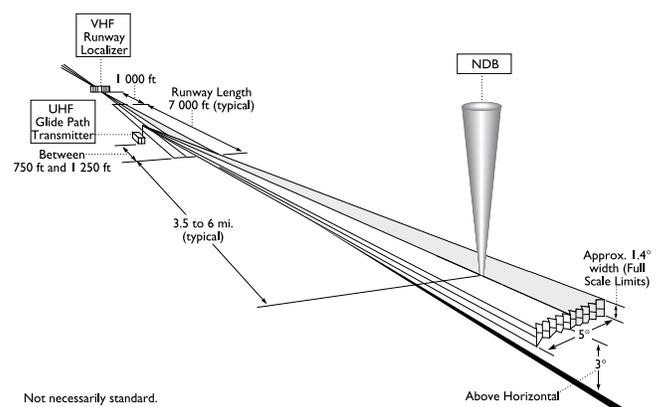
LOC and glide path identification is transmitted on the LOC frequency in the form of a two-letter or letter-number indicator preceded by the letter “I” (e.g. IOW).

4.10.2 Glide Path (GP)

The glide path transmitter operates within the frequency range of 329.3 to 335 MHz. The frequency is paired with the associated LOC frequency in accordance with ICAO standards. The glide path is adjusted to a published approach angle (typically 3°) and a beam width of 1.4°. The antenna array is located approximately 1 000 ft from the approach end of the runway and offset approximately 400 ft from the runway centreline. As the glide path is formed by reflecting the transmitted signal off the ground, the beam-forming area in front of the glide path antenna can be negatively affected by heavy snow buildup. Airports have snow-clearing plans in effect for this area as the snow must remain below the allowable design depth for proper glide path operation.

At some of the larger airports, an ILS is installed at each end of a runway. Consequently, an approach may be designed to either end of the runway. The two systems are interlocked so that only one ILS can operate at any time.

Figure 4.1—Typical ILS Installation



4.10.3 Non-directional Beacon (NDB)

Low-power NDB transmitters are sometimes located on the LOC, 3.5 to 6 mi. from the runway threshold. If it is not possible to install an NDB, a DME fix or RNAV fix may be used instead to form the FAF. In some cases, an en route NDB is located on a LOC so that it may serve as a terminal as well as an en route facility. As a general rule, NDBs transmit a two- or three-letter indicator. The FAF provides a fix to which the pilot can navigate for the transition to the ILS.

4.10.4 Instrument Landing System (ILS)/Distance Measuring Equipment (DME)

At some locations, a DME paired with the ILS provides distance information to define the IAF and MAP. At other locations, VOR/DME, which are available either on the airport or aligned with the appropriate runway, will be used to provide distance information for the transition to the ILS.

4.10.5 Instrument Landing System (ILS) Categories

Operational CAT I—Operation down to a minima of 200 ft DH and an RVR of 2 600 ft with a high probability of success. (When RVR is not available, 1/2 SM ground visibility is substituted.)

Operational CAT II—Operation down to a minima below 200 ft DH and an RVR of 2 600 ft, to as low as 100 ft DH and an RVR of 1 200 ft, with a high probability of success.

Operational CAT III—CAT III minima will be prescribed in the carrier's operating specifications, in the operator's operations manual, or in the CAP.

4.10.6 Category II/III Instrument Landing System (ILS)

CAT II/III ILS enable pilots to conduct instrument approaches to lower weather minima by using special equipment and procedures in the aircraft and at the airport.

The following airport systems must be fully serviceable to meet CAT II/III standards:

(a) *Airport lighting*—A lighting system which includes:

- (i) approach lights;
- (ii) runway threshold lights;
- (iii) touchdown zone lights;
- (iv) centreline lights;
- (v) runway edge lights;
- (vi) runway end lights;
- (vii) all stop bars and lead-on lights;
- (viii) essential taxiway lights.

(b) *ILS components*—Including:

- (i) LOC;
- (ii) glide path transmitter;
- (iii) NDB, DME or RNAV fix.

(c) *RVR equipment*—For CAT II operations, two RVRs: one located adjacent to the runway threshold (touchdown or RVR A), and one located adjacent to the runway mid-point (mid-point or RVR B). For CAT III operations, three RVRs: one located adjacent to the runway threshold (touchdown or RVR A), one located adjacent to the runway mid-point (mid-point or RVR B), and one located at the stop-end (rollout or RVR C) of the runway (ref. ICAO Annex 3, 4.6.3.4).

(d) *Power source*—Airport emergency power (primary electrical source for all essential system elements), commercial power available within one second as backup.

4.10.7 Caution Regarding Use of Instrument Landing System (ILS)

Low clearance indications—Course interference is negligible when aircraft are flown within 6° on either side of the course centreline. Actual anomalies are typically noted on the applicable approach charts. However, failure of certain elements of some multi-element LOC antenna array systems can cause false courses or low clearances* beyond 6° from the centreline that are not detected by the LOC monitoring system. This could result in a premature cockpit indication of approaching or intercepting an on-course centreline. For this reason, a coupled approach should not be initiated until the aircraft is established within 6° of the LOC centreline. It is also essential to confirm the LOC on-course indication by reference to the aircraft's heading and other NAVAIDs (such as an ADF bearing or RNAV track) before commencing final descent. Any abnormal indications experienced within 35° of the published centreline of an ILS LOC should be reported immediately to the appropriate ATS facility.

*A low clearance occurs whenever there is less than full-scale deflection of the omnibearing selector or CDI at a position where a full-scale deflection should be displayed outside of 6° from the LOC centreline.

LOC false course—False course captures may occur when the pilot prematurely selects APPROACH MODE from either HDG or LNAV MODE. Some ILS receivers produce lower than expected course deviation outputs in the presence of high modulation levels of the LOC-radiated signal. This can occur even when both the ground transmitter and the airborne receiver meet their respective performance requirements. The reduced course deviation can, in turn, trigger a false course capture in the AFCS. False course captures can occur at azimuths of anywhere from 6° to 35° but are most likely to occur in the vicinity of 6° to 10° azimuth from the published LOC course. A false capture is deemed to have occurred when the AFCS allows the LOC to switch from ARMED to CAPTURED even though the omnibearing selector or CDI has not moved and is still at full-scale deflection.

In order to minimize the possibility of a false course capture during an ILS approach, pilots should use raw data sources to ensure that the aircraft is within 6° of the correct LOC course prior to initiating a coupled approach. The following cockpit procedures are recommended:

(a) APPROACH MODE should not be selected until the aircraft is within 18 NM of the threshold and is positioned within 6° of the inbound ILS course.

- (b) In addition, pilots should:
- (i) ensure that the ADF bearing (associated with the appropriate NDB site) or RNAV track for the runway is monitored for correct orientation;
 - (ii) be aware when the raw data indicates that the aircraft is approaching and established on the correct course; and
 - (iii) be aware that, should a false course capture occur, it will be necessary to deselect and re-arm APPROACH MODE in order to achieve a successful coupled approach on the correct LOC course.

EMI—The effect of EMI, particularly on ILS LOC system integrity, is becoming increasingly significant. In built-up areas, power transformer stations, industrial activity, and broadcast transmitters have been known to generate interference that affects LOC receivers. The effect is difficult to quantify as the interference may be transitory, and certain LOC receivers are more susceptible than others to EMI. If the LOC goes off the air, the “off” flag may remain out of sight or the flag and CDI may give erratic or erroneous indications. It is even possible that normal on-course cockpit indications may continue. Under normal circumstances, ATIS will advise pilots conducting an approach if there is equipment failure.

Automatic landing (autoland) operations—The commissioning, periodic flight inspection, and maintenance of the ILS facility serving a CAT III runway include an analysis of the ILS LOC signal throughout the rollout to confirm that the ILS facility will support CAT III operations. The successful outcome of any ILS autoland depends on the performance of the aircraft’s AFCGS and the ILS LOC and glide path signals. The course structure and the integrity of an ILS can be compromised when protection of the ILS critical areas is not assured. The LOC is particularly sensitive due to its larger signal volume in the aerodrome area. Surface and airborne traffic as well as vehicles that are crossing or parked in these critical areas can create a deflection in or a disturbance to the ILS signal. An ILS CAT III signal is only protected by ATIS when low visibility procedures are in effect at that aerodrome.

It has been common practice for operators of appropriately equipped and certified aircraft to conduct AFCGS autoland operations at CAT I, II, or III facilities when weather conditions are above the appropriate minima to satisfy maintenance, training, or reliability program requirements. A portion of these autolands may also need to be conducted on CAT I ILS facilities, or on CAT II/III ILS facilities when low visibility procedures are not in force. In the case of a CAT I ILS facility, for example, the ILS should be of CAT II signal quality without necessarily meeting the associated CAT II reliability and availability criteria for backup equipment and automatic changeover of facility performance.

Some CAT I and II ILS facilities that have the signal characteristics to support AFCGS operations to CAT I and II minima, as applicable, may not have the requisite signal characteristics to support autoland operations. NAV CANADA maintains a list indicating which facilities are suitable for autoland practice. The list is available here: <https://www.navcanada.ca/en/flight-planning/communication-navigation-and-surveillance.aspx/#e4970b9b30a240fd99eaa339c4316d66>.

Flight crews are reminded to exercise extreme caution whenever ILS signals are used beyond the minima specified in the approach procedure and when conducting autolands on any category of ILS when critical area protection is not assured by ATIS. Pilots must be prepared to immediately disconnect the autopilot and take appropriate action should unsatisfactory AFCGS performance occur during these operations.

Glide path fluctuations—While an aircraft is navigating on the ILS, fluctuations may occur when other aircraft or vehicles are moving through the glide path critical area, causing interference with the signal. In some cases, the aircraft automation/autopilot may follow momentary fluctuations, causing the aircraft to pitch or roll. ATIS will protect the glidepath signal when:

- (a) The ceiling is less than 1 000 ft or visibility is less than 3 miles, or both; and
- (b) The arriving aircraft is inside the FAF on an ILS approach.

The ILS critical areas are not protected when aircraft are outside the FAF. Furthermore, except for CAT II/III operations, localizer signal protection is not applied when a preceding aircraft passes over or through the critical area while taking off, landing, or executing a missed approach on the same or another runway. Pilots must be aware of ILS signal interference threats as well as flight display indications and autopilot functionality during manual or fully coupled ILS approaches.

In situations where protection of the ILS signal is not required but a pilot wishes to conduct autoland or practise low-visibility procedures, the pilot must advise the controller of these intentions early enough so that the controller can either protect the ILS critical area or advise the pilot that, due to traffic, ILS critical area protection is not possible. If ILS critical area protection is not possible, the controller will use the phrase “ILS CRITICAL AREA NOT PROTECTED”. It then becomes the pilot’s responsibility to continue the chosen approach mode.

Pilots should review Transport Canada’s *Manual of All Weather Operations* for an understanding of ILS critical and sensitive areas.

NOTE: At uncontrolled airports, aircraft manoeuvring on the ground may enter ILS critical areas during taxi, takeoff, or landing.

- (c) *Glide path false course*—The normal antenna pattern of glide path installations produces a false glide path angle at two and three times the set angle (e.g. at 6° and 9° for a typical 3° published glide path angle).

ATC procedures in terminal areas are designed to maintain aircraft at an altitude that provides a normal rate of descent and a suitable position to capture the published glide path signal. Following the instrument procedures carefully will ensure both an approach with a stable rate of descent and the complete avoidance of a false glide path. Failure to adhere to instrument procedures (e.g. remaining at an altitude higher than published) could result in positioning the aircraft in a false glide path created by the radiated lobe.

In order to minimize the possibility of false glide path capture during an ILS approach, pilots should verify the rate of descent and the altitude at the FAF to ensure that the aircraft is on the published glide path.

5.0 AREA NAVIGATION (RNAV)

Area navigation (RNAV) is a method of navigation which permits aircraft operation on any desired flight path within the coverage of navigation aids (NAVAIDs) or within the limits of the capability of self-contained NAVAIDs, or a combination of these.

Existing navigation systems which provide an area navigation (RNAV) capability include the global navigation satellite system (GNSS), VHF omnidirectional range (VOR)/distance measuring equipment (DME) (RHO-THETA), DME-DME (RHO-RHO), inertial navigation system (INS) and inertial reference system (IRS).

5.1 GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS)

The global navigation satellite system (GNSS) is a worldwide position and time determination system that includes one or more satellite constellations, aircraft receivers and system integrity monitoring, augmented as necessary to support the required navigation performance for the intended operation.

5.2 GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS) CONSTELLATIONS

Currently, there are two complete navigation satellite constellations in orbit: the U.S. global positioning system (GPS) and the Russian global orbiting navigation satellite system (GLONASS). The U.S. and Russia have offered these systems as the basis of a global navigation satellite system (GNSS) that is free of direct user charges. Additional constellations are being developed by the European Union (Galileo), and by China (BeiDou). Instrument flight rules (IFR) certified GNSS receivers manufactured in North America use only the GPS constellation, but plans are underway to expand that ability.

5.2.1 Global Positioning System (GPS)

The GPS constellation was developed by the U.S. military; however, since 1996, it has been managed by an executive board,

chaired jointly by the departments of Defense and Transportation, that is comprised of representatives from several other departments to ensure that civil user requirements are considered in the management of the system. Title 10 of the *U.S. Code*, Section 2281, assigns the Secretary of Defense statutory authority to sustain and operate GPS for military and civil purposes. This statute directs the Secretary of Defense to provide civil GPS service on a continuous, worldwide basis, free of direct user fees. The system is operated and controlled by Space Delta 8, located at Schriever Space Force Base, Colo.

The design GPS constellation contains 24 GPS satellites, orbiting the earth twice a day at an altitude of 10 900 NM (20 200 km). They are arranged in six separate orbital planes, with four satellites in each; this gives complete global coverage. There are approximately 32 operational satellites; however, at any given time, one or more may be decommissioned or be out of service temporarily for maintenance.

All GPS orbits cross the equator at a 55° angle, so it is not possible to see a GPS satellite directly overhead when north of 55° N or south of 55° S latitude. This does not affect service in polar areas adversely; in fact, on average, more GPS satellites are visible at high latitudes since receivers can track satellites on the other side of the pole.

GPS positioning is based on precise timing. Each satellite has four atomic clocks on board, guaranteeing an accuracy of one billionth of one second, and broadcasts a digital PRN code that is repeated every millisecond. All GPS satellites start generating the same code at the same time. Code matching techniques establish the time of arrival difference between the generation of the signal at the satellite and its arrival at the receiver. The speed of the signal is closely approximated by the speed of light, with variations resulting from ionospheric and atmospheric effects modeled or directly measured and applied. The time of arrival difference is converted to a distance, referred to as a pseudorange, by computing the product of the time of arrival difference and the average speed of the signal. The satellites also broadcast orbit information (ephemeris) to permit receivers to calculate the position of the satellites at any instant in time.

Normally, SVNs are sequential (i.e. SVN 68 was the sixty-eighth satellite launched), but PRN codes are assigned to a position in the constellation, and are numbered PRN 1 to 24 (with a maximum of 32).

A receiver normally needs four pseudoranges to calculate a three-dimensional position and to resolve the time difference between receiver and satellite clocks. In addition to position and time, GPS receivers can also calculate velocity—both speed and direction of motion.

GPS accuracy depends on transit time and signal propagation speed to compute pseudoranges. Therefore, accurate satellite clocks, broadcast orbits, and computation of delays as the signals pass through the ionosphere are critical. The ionosphere, which is a zone of charged particles several hundred kilometres above the Earth, causes signal delays that vary from day to night and by solar activity. Current receivers contain a model of the nominal day/night delay, but this model does not account for variable solar activity. For applications requiring high accuracy, GPS

needs an augmentation system to correct the computed transit time to compensate for this delay.

Another key to GPS accuracy is the relative position of satellites in the sky, or satellite geometry. When satellites are widely spread, geometry and accuracy are better. If satellites are clustered in a small area of the sky, geometry and accuracy are worse. Currently, GPS horizontal and vertical positions are accurate to 6 m and 8 m, respectively, 95% of the time.

The GPS satellite constellation is operated by the U.S. Air Force from a control centre at Schriever Space Force Base in Colorado. A global network of monitor and uplink stations relays information about the satellites to the control centre and sends messages, when required, to the satellites.

If a problem is detected with a satellite, it is commanded to send an “unhealthy” status indication, causing receivers to drop it from the position solution. Since detection and resolution of a problem take time, and this delay is unacceptable in aviation operations, augmentation systems are used to provide the level of integrity required by aviation.

The GPS constellation status is available at <http://www.navcen.uscg.gov/?Do=constellationStatus>.

5.2.2 Global Orbiting Navigation Satellite System (GLONASS)

GLONASS is a global satellite constellation, operated by the Russian Aerospace Defence Forces, that provides real-time position and velocity determination for military and civilian users. The satellites are located at an altitude of 19 100 km and at an inclination of the orbital planes of 64.8° to the equator.

The GLONASS constellation status is available at <https://glonass-iac.ru/en/sostavOG/>.

5.2.3 Galileo Navigation Satellite System

Galileo is Europe’s GNSS constellation, which will provide a highly accurate, guaranteed global positioning service under civilian control. The fully deployed Galileo system will consist of 24 operational satellites plus six in-orbit spares, positioned in three circular medium Earth orbit (MEO) planes at an altitude of 23 222 km, and at an inclination of the orbital planes of 56° to the equator.

The Galileo constellation status is available at <https://www.gsc-europa.eu/system-status/Constellation-Information>.

5.2.4 BeiDou Navigation Satellite System

BeiDou is the Chinese navigation satellite system. It consists of two separate satellite constellations: a limited test system that has been operating since 2000 and a full-scale global navigation system that is currently under construction. On June 23, 2020, the final BeiDou satellite was successfully launched. It was the 55th satellite in the BeiDou family. The third iteration of the BeiDou navigation satellite system provides full global coverage for timing and navigation.

The BeiDou constellation status is available at www.csno-tarc.cn/en/.

5.3 AUGMENTATION SYSTEMS

Augmentation of the global positioning system (GPS) constellation or the global orbiting navigation satellite system (GLONASS) constellation is required to meet the accuracy, integrity, continuity and availability requirements for aviation. There are currently three types of augmentation:

- aircraft-based augmentation system (ABAS);
- satellite-based augmentation system (SBAS); and
- ground-based augmentation system (GBAS).

5.3.1 Aircraft-Based Augmentation System (ABAS)

RAIM and FDE functions in current IFR-certified avionics are considered ABAS. RAIM can provide the integrity for the en route, terminal, and NPA phases of flight. FDE improves the continuity of operation in the event of a satellite failure and can support primary-means oceanic operations.

RAIM uses extra satellites in view to compare solutions and detect problems. It usually takes four satellites to compute a navigation solution, and a minimum of five for RAIM to function. The availability of RAIM is a function of the number of visible satellites and their geometry. It is complicated by the movement of satellites relative to a coverage area and temporary satellite outages resulting from scheduled maintenance or failures.

If the number of satellites in view and their geometry do not support the applicable alert limit (2 NM en route, 1 NM terminal and 0.3 NM NPA), RAIM is unable to guarantee the integrity of the position solution. (Note that this does not imply a satellite malfunction.) In this case, the RAIM function in the avionics will alert the pilot, but will continue providing a navigation solution. Except in cases of emergency, pilots must discontinue using GNSS for IFR navigation when such an alert occurs.

A second type of RAIM alert occurs when the avionics detects a satellite range error (typically caused by a satellite malfunction) that may cause an accuracy degradation that exceeds the alert limit for the current phase of flight. When this occurs, the avionics alerts the pilot and denies navigation guidance by displaying red flags on the HSI or CDI. Continued flight using GNSS is then not possible until the satellite is flagged as unhealthy by the control centre, or normal satellite operation is restored.

Some avionics go beyond basic RAIM by having an FDE feature that allows the avionics to detect which satellite is faulty, and then to exclude it from the navigation solution. FDE requires a minimum of six satellites with good geometry to function. It has the advantage of allowing continued navigation in the presence of a satellite malfunction.

Most first generation avionics do not have FDE and were designed when GPS had a feature called SA that deliberately degraded accuracy. SA has since been discontinued, and new generation SBAS-capable receivers (TSO-C145a/C146a) account for SA being terminated. These receivers experience a higher RAIM availability, even in the absence of SBAS messages, and also have FDE capability.

For avionics that cannot take advantage of SA being discontinued, average RAIM availability is 99.99% for en-route and 99.7% for NPA operations for a 24-satellite GPS constellation. FDE availability ranges from 99.8% for en route to 89.5% for NPA. Avionics that can take advantage of SA having been discontinued have virtually 100% availability of RAIM for en route and 99.998% for NPA; FDE availability ranges from 99.92% for en route to 99.1% for NPA. These figures have been computed for mid-latitudes, and are dependent on user position and also on which satellites are operational at any given time. RAIM and FDE availability is typically even better at high latitudes, since the receiver is able to track satellites on the other side of the North Pole.

The level of RAIM or FDE availability for a certain airspace at a certain time is determined by an analysis of satellite geometry, rather than signal measurement. This is why it can be predicted by receivers or with PC-based computer software. The difference between the two methods is that the receivers use the current constellation in their calculations while the PC software can use a constellation definition that takes into account scheduled satellite outages.

Most TSO-C129a avionics also accept signals from an aircraft altitude encoder. This is called baro-aiding, and it essentially reduces the number of satellites required by one, thus further increasing the availability of RAIM and providing an additional measure of tolerance to satellite failures.

With proper integration, IRS and INS can augment/enhance GNSS navigation. This system allows “coasting” through periods of low availability.

5.3.2 Satellite-Based Augmentation System (SBAS)

SBAS uses a network of ground-based reference stations that monitor navigation satellite signals and relay data to master stations, which assess signal validity and compute error corrections. The master stations generate two primary types of messages: integrity, and range corrections. These are broadcast to SBAS-capable GNSS receivers via GEO satellites in fixed orbital positions over the equator. The SBAS GEO satellites also serve as additional sources of navigation ranging signals.

The integrity messages provide a direct validation of each navigation satellite’s signal. This function is similar to RAIM, except that the additional satellites required for RAIM are not necessary when SBAS integrity messages are used. The integrity messages are available wherever a GEO satellite signal can be received.

The range corrections contain estimates of the errors introduced into the range measurements as a result of ionospheric delays, and satellite ephemeris (orbit) and clock errors. Ionospheric delay terms are critical for correction messages, and are also the most challenging to characterize. First, each reference station measures the ionospheric delay for each visible satellite. These observations are sent to the master station, where they are combined, and used to generate a model of the ionosphere, which is then transmitted to the receivers via the GEO satellite. The accuracy of the model is dependent on the number and placement of the reference stations providing observations of ionospheric

delays.

By compensating for these errors, SBAS-capable GNSS receivers can compute the position of the aircraft with the accuracy necessary to support flight operations with vertical guidance. Vertical guidance provides safer stabilized approaches and transition to visual for landing. This represents one of the principal benefits from SBAS service. The other is lower approach minima at certain airports, as a result of greater lateral accuracy.

The first SBAS, the U.S. FAA’s wide area augmentation system (WAAS), was commissioned in 2003. Europe has built a compatible system called EGNOS (European geostationary navigation overlay service) which was approved for aviation use in August 2010. Japan and India also have similar systems to augment GNSS: MSAS (MTSAT satellite-based augmentation system) and GAGAN (GPS and GEO augmented navigation), respectively.

WAAS messages are broadcast by geostationary satellites located on the equator. See the following Web site for their exact locations: <https://www.nstb.tc.faa.gov/index.htm>.

5.3.3 Ground-Based Augmentation System (GBAS)

GBAS, also known as LAAS, sends corrections directly to GBAS-capable receivers from a ground station at an airport.

GPS receivers with antennas at surveyed surface locations provide measurements used to generate and broadcast pseudorange corrections. Aircraft receivers use the corrections for increased accuracy, while a monitor function in the ground station assures the integrity of the broadcast. GBAS provides service over a limited area, typically within 30 NM of the ground station.

GBAS is not yet available in Canada.

5.4 DOMESTIC INSTRUMENT FLIGHT RULES (IFR) APPROVAL TO USE GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS) AND SATELLITE-BASED AUGMENTATION SYSTEM (SBAS)

The global navigation satellite system (GNSS) and satellite-based augmentation system (SBAS) approved for instrument flight rules (IFR) use in Canada are listed in *AIP Canada* ENR 4.3, Table 4.3.

GNSS capability may be provided by a panel-mount receiver or by a flight management system (FMS) that uses the appropriate sensor.

Avionics are required to meet appropriate equipment standards and, equally important, the avionics installation must be approved by Transport Canada (TC) to ensure proper avionics integration and display.

Handheld and other visual flight rules (VFR) receivers do not support integrity monitoring, nor do they comply with other certification requirements; therefore, they cannot be used for IFR operations.

Holders of air operator certificates (AOCs) issued under Part VII of the *Canadian Aviation Regulations* (CARs) and private operator certificates issued under CAR 604 are required to be authorized to conduct GNSS instrument approach operations in instrument meteorological conditions (IMC).

5.4.1 Domestic En Route and Terminal Operations

In practice, pilots can use GNSS for guidance most of the time. If an integrity alert occurs while en route, the pilot can then continue by using conventional aids, diverting if necessary from the direct routing, notifying ATS of any changes to the flight and obtaining a new clearance, as required.

When using GNSS to maintain a track in terminal operations, the avionics shall be in terminal mode and/or the CDI shall be set to terminal sensitivity. (Most avionics set the mode and sensitivity automatically within 30 NM of the destination airport, or when an arrival procedure is loaded.)

When using GNSS to navigate along VHF/UHF or LF/MF airways, ground-based NAVAID reception is not an issue. This means that pilots using GNSS for navigation can file or request an altitude below the MEA, but at or above the MOCA, to avoid icing, optimize cruise altitude, or in an emergency. However, an ATS clearance to fly at a below-MEA altitude could be dependent on issues such as radiocommunication reception and the base of controlled airspace. In the rare case of a RAIM alert while en route below the MEA, and out of range of the NAVAID, pilots should advise ATS and climb to continue the flight using alternate means of navigation.

GNSS avionics typically display the distance to the next waypoint. To ensure proper separation between aircraft, a controller may request the distance from a waypoint that is not the currently active waypoint in the avionics; it may even be behind the aircraft. Pilots must be able to obtain this information quickly from the avionics. Techniques vary by manufacturer, so pilots should ensure familiarity with this function.

At times outside ATS surveillance coverage, pilots may be cleared by ATS to a position defined by a latitude and longitude. As these are usually outside the range of traditional NAVAIDs, there is no means to cross check that the coordinates have been entered accurately. Pilots must be particularly careful to verify that the coordinates are correct.

5.4.2 Global Navigation Satellite System (GNSS)-Based Area Navigation (RNAV) Approach Procedures

Prior to the advent of GNSS, only two types of approach and landing operations were defined: precision approach and NPA. Definitions have now been added for APV to cover approaches that use lateral and vertical guidance, but that do not meet the requirements established for precision approaches.

GNSS-based approaches are charted as “RNAV (GNSS) RWY XX.” The “(GNSS)” before the runway identification indicates that GNSS must be used for guidance. Pilots and controllers

shall use the prefix “RNAV” in radio communications (e.g. “CLEARED TO THE VANCOUVER AIRPORT RNAV RUNWAY ZERO FOUR APPROACH”).

GNSS-based RNAV approaches are designed to take full advantage of GNSS capabilities. A series of waypoints in a “T” or “Y” pattern eliminates the need for a procedure turn. The accuracy of GNSS may result in lower minima and increased capacity at the airport. Because GNSS is not dependent on the location of a ground-based aid, straight-in approaches are possible for most runway ends at an airport.

In Canada, RNAV (GNSS) approach charts may depict up to five sets of minima:

- (a) LPV;
- (b) LP;
- (c) LNAV/VNAV;
- (d) LNAV; and
- (e) CIRCLING.

The LP and LNAV minima indicate an NPA, while the LNAV/VNAV and LPV minima refer to APV approaches (RNAV approaches with vertical guidance). However, the actual terms “NPA” and “APV” do not appear on the charts because they are approach categories not related to specific procedure design criteria. In Canada, the depiction of the five sets of minima is similar to the way that an ILS approach may show landing minima for ILS, LOC and CIRCLING.

The approach chart may indicate a WAAS channel number. This is used for certain types of avionics and permits the approach to be loaded by entering the number shown.

All approaches must be retrieved from the avionics database, and that database must be current. While it is sometimes acceptable to use pilot-generated waypoints en route, this is not permitted for approach procedures.

5.4.2.1 Area Navigation (RNAV) Approaches with Lateral Guidance Only

Avionics for LNAV approaches do not define a vertical path through space; as such, each approach segment has a minimum altitude below which the pilot may not descend.

GPS (TSO-C129/C129a Class A1, B1, B3, C1 or C3) and WAAS (TSO-C145a/C146a, any class) avionics are both able to provide the lateral guidance required for these approaches.

Without vertical guidance, pilots are required to remain at or above the MDA unless a visual transition to landing can be accomplished, or to conduct a missed approach at the MAWP, typically located over the runway threshold.

WAAS and some GPS TSO-C129/C129a avionics may provide advisory vertical guidance when flying approaches without LNAV/VNAV or LPV minima. It is important to recognize that this guidance is advisory only and the pilot is responsible for respecting the minimum altitude for each segment until a visual transition to land is commenced.

Pilots using TSO-C129/C129a avionics should use the RAIM prediction feature (including known satellite outages obtained by NOTAM at KGPS) to ensure that approach-level RAIM will be supported at the destination or alternate airport for the ETA (± 15 min). This should be done before takeoff, and again prior to commencing a GNSS-based approach. If approach-level RAIM is not expected to be available, pilots should advise ATS as soon as practicable and state their intentions (e.g. delay the approach, fly another type of approach, proceed to alternate).

5.4.2.2 Vertical Guidance on Area Navigation (RNAV) Approaches

LNAV/VNAV and LPV describe approaches with vertical guidance. These deliver the safety benefits of a stabilized approach and, in many cases, improve airport accessibility.

Aircraft with TSO-C145a/C146a (WAAS Class 2 or 3) or TSO-C115b (multi-sensor FMS) avionics, may fly RNAV (GNSS) approaches to LNAV/VNAV minima with vertical guidance in a similar manner to the way they fly an ILS approach: with both a lateral CDI and a VDI. The lateral guidance must be based on GPS or WAAS. The vertical guidance may be based on WAAS, or on barometric inputs (baro-VNAV), depending on the approach and the aircraft equipage.

Aircraft with WAAS Class 3 avionics may fly RNAV (GNSS) approaches to LPV minima in a similar manner. In this case, both the lateral and vertical guidance are based on WAAS.

The nominal final approach course vertical flight path angle for LNAV/VNAV and LPV approaches is 3° , avoiding the step-down minimum altitudes associated with traditional NPAs.

The LNAV/VNAV and LPV minima depict a DA, which requires the pilot to initiate a missed approach at the DA if the visual reference to continue the approach has not been established.

5.4.2.3 Area Navigation (RNAV) Approaches with Vertical Guidance Based on Barometric Vertical Navigation (Baro-VNAV)

Multi-sensor FMSs that meet TSO-C115b have been certified since the late 1980s to provide guidance for a stabilized final approach segment during NPAs. The vertical guidance for these systems has been derived from a barometric altitude input; hence, these approaches are known as baro-VNAV approaches. This equipment has typically only been installed on transport category aeroplanes. The information provided by these systems is advisory only, and pilots are required to respect all minimum altitudes, including step-down altitudes, since NPAs are not specifically designed to take advantage of baro-VNAV capability.

With the publication in Canada of RNAV (GNSS) approaches with vertical guidance, suitably-equipped aircraft may fly baro-VNAV approaches to the LNAV/VNAV minima published on these approach plates. The standard for equipage is a multi-sensor FMS that meets TSO-C115b and is certified in accordance with FAA AC 20-138C or equivalent. The FMS must use GNSS sensor input, but does not require a WAAS-capable receiver to fly to LNAV/VNAV minima. Pilots must note that the vertical path defined by baro-VNAV is affected by altimeter setting

errors. For this reason, baro-VNAV is not authorized unless a local field altimeter setting is available.

Non-standard atmospheric conditions, particularly temperature, also induce errors in the baro-VNAV vertical path. A nominal 3° glide path will be steeper at warmer temperatures and shallower at lower temperatures. To compensate for these temperature effects, some avionics allow input of the temperature at the airport and apply temperature compensation to the vertical path angle so that the baro-VNAV vertical path is not biased as a function of temperature. Unfortunately, not all systems have similar capabilities to compensate for temperature effects, and pilots need to understand their system's capabilities.

When temperature compensation is not or cannot be applied through the FMS, pilots shall refer to a temperature limit, referred to as TLim, published on the approach chart. This limiting temperature protects a baro-VNAV's final segment vertical path only (it does not protect any of the published minimum IFR altitudes on the chart). Below this temperature, the uncompensated vertical path generated by the FMS will not provide the required obstacle protection. Therefore, when the temperature is below the published TLim, an aircraft with an uncompensated baro-VNAV system shall not fly an RNAV approach to LNAV/VNAV minima. TLim will be a function of the reduced obstacle clearance resulting from flying an uncompensated VPA and will vary from approach to approach. For avionics systems that have the capability to correctly adjust the VPA for temperature deviations, the published TLim does not apply if the pilot enables the temperature compensation.

In short, regardless of whether or not the FMS (or other automated means) provides temperature compensation of the vertical path, and whether or not the actual reported airport temperature is within the temperature limit for the procedure, pilots are responsible for correcting the temperature of all minimum published IFR altitudes on the approach, including the DA.

5.4.2.4 Area Navigation (RNAV) Approaches with Vertical Guidance Based on Wide Area Augmentation System (WAAS)

RNAV (GNSS) approaches with vertical guidance based on WAAS require a Class 2 or 3 (for LNAV/VNAV minima) or Class 3 (for LPV minima) TSO-C145a WAAS receiver, or a TSO-C146a sensor interfaced to appropriate avionics.

RNAV (GNSS) approaches with vertical guidance based on WAAS are entirely dependent on the WAAS signal. WAAS meets essentially the same navigation performance requirements (accuracy, integrity and continuity) as ILS, and pilots can expect guidance to be similar to that provided by an ILS, with some improvement in signal stability over ILS.

WAAS avionics continuously calculate horizontal and vertical protection levels during an approach and will provide a message to the crew if alert limits for the procedure are exceeded, similar to the way in which ILS monitors shut down an ILS signal when its accuracy does not meet the required tolerances.

Although the WAAS integrity monitor is very reliable, good airmanship nevertheless dictates that pilots verify the FAWP

crossing altitude depicted on approach plates with LNAV/VNAV and LPV minima, in the same way that the glide path check altitude is used when flying an ILS approach. Large altitude deviations could be an indication of a database error or otherwise undetectable incorrect signal.

5.5 FLIGHT PLANNING

NOTAM on ground-based navigation aid (NAVAID) outages are of direct use to pilots because if a NAVAID is not functioning, the related service is not available. With the global positioning system (GPS) and wide area augmentation system (WAAS), the knowledge of a satellite outage does not equate to a direct knowledge of service availability. The procedures for determining service availability are different for GPS (TSO-C129/C129a) and WAAS (TSO-C145a/C146a) avionics, and are explained in the next subsections.

5.5.1 Global Positioning System (GPS) NOTAM

NOTE:

This section applies only to operators using TSO-C129/C129a avionics.

Research has shown minor differences among avionics' computations of RAIM availability, making it impractical to develop a GPS RAIM NOTAM system that will work reliably for all receivers. Because of this, and since IFR GPS approval requires aircraft to be equipped with traditional avionics to be used when RAIM is unavailable, NOTAM information on GPS RAIM availability is not provided in Canada. Canadian FICs can supply NOTAM on GPS satellite outages by querying the international NOTAM identifier KGPS. (This information is also available at <www.notams.faa.gov>.) The availability of RAIM can then be computed from the satellite availability information by entering the expected outages into PC-based RAIM prediction software provided by some avionics manufacturers or through direct entry into the GNSS receiver or FMS computers that support this function.

GNSS avionics also contain such a model, and this allows pilots to determine if approach-level RAIM will be supported (available) upon arrival at destination or at an alternate. The calculation typically uses current information, broadcast by the satellites, identifying which satellites are in service at that time. However, unlike the software that is based on the NOTAM data, this prediction does not always take into account scheduled satellite outages.

Operators using TSO-C129/C129a avionics who wish to take advantage of an RNAV (GNSS) approach when specifying a destination or alternate airport must check KGPS NOTAM to verify the status of the constellation.

5.5.2 Wide Area Augmentation System (WAAS) NOTAM

A NOTAM will be issued whenever the FAA advises NAV CANADA that LPV, LP and WAAS-based LNAV/VNAV service is unavailable for a period of more than 15 min. The NOTAM is issued for the FIR and will read either:

- (a) LPV, LP AND WAAS-BASED LNAV/VNAV APCH NOT AVBL (and may include a description of the affected area, if WAAS messages issued by a particular WAAS satellite are not available); or
- (b) WAAS UNMONITORED (indicating that WAAS messages may not be available across the entire service area).

Pilots should flight plan based on the assumption that the services referred to in a NOTAM will not be available. However, once they arrive at the aerodrome, they may discover that a service is in fact available, in which case they may use the approach safely if they so choose.

When LPV, LP and WAAS-based LNAV/VNAV are not available, pilots may fly the LNAV procedure to the published MDA, as this will almost always be available to pilots using WAAS avionics. Since LNAV procedures will be used when LPV and LNAV/VNAV are not available, pilots should ensure that they maintain their skills in flying these approaches.

NOTE:

WAAS NOTAM information is not applicable to users of TSO-C129a avionics.

NOTAM examples can be found in the *Canadian NOTAM Operating Procedures*, available here: <<https://www.navcanada.ca/en/aeronautical-information/operational-guides.aspx>>.

5.5.3 Procedures on the Fringe of Wide Area Augmentation System (WAAS) Coverage

When WAAS coverage for an aerodrome is expected to be marginal or unavailable, WAAS-based approach procedures will normally not be designed. However, at aerodromes on the fringe of WAAS coverage areas, for which LPV-, LP- or WAAS-based LNAV/VNAV lines of minima have been published, pilots will be alerted that occasional outages may occur by a note on the chart that states: "Procedure on the fringe of WAAS coverage. Occasional outages may occur."

Pilots should flight plan as though LPV-, LP- and WAAS-based LNAV/VNAV will not be available at these aerodromes; however, if the service is available, it may be used safely at the pilot's discretion.

5.5.4 Space Weather

The source of space weather is the sun, which releases streams of charged particles made up of energized electrons and protons.

Two types of solar phenomena can have a major impact on GNSS: coronal mass ejections (CMEs) and coronal holes. Coronal mass ejections are gigantic amounts of electrified gas or plasma launched into space that can have a major influence, typically reaching the Earth within 1–3 days. Coronal holes are regions

of open magnetic field lines where high-speed streams of plasma can flow out from the sun. If conditions are right when these particles reach the Earth, geomagnetic storms can occur.

At the Earth's surface, geomagnetic storms are characterized by a K-level index that ranges from 0–9. Storms having little effect would range from 0–3, while those with moderate effects would be 4–7, and strong storms with a lot of impact would be > 7. The Canadian Space Weather Forecast Centre (CSWFC) monitors, analyzes and forecasts space weather. Based on solar observations, it can predict when the particles will reach the Earth, and forecast the expected geomagnetic activity that will result. More detailed measurements are made using space weather monitoring satellites, which provide information approximately 30 min before the particles reach the Earth.

Canada has three zones of geomagnetic activity: the polar cap, the auroral zone and the subauroral zone. The highest geomagnetic activity and greatest disturbances are observed in the auroral zone. Changes in electron density, due to space weather activity, can change the speed at which radio waves travel, introducing a “propagation delay” in the GNSS signal through the ionosphere. The propagation delay can vary from minute to minute, and these intervals of rapid change can sometimes last for several hours, especially in the polar and auroral regions. Changing propagation delays cause errors in the determination of the range.

ABAS, SBAS and GBAS use different techniques to correct for ionospheric delays. ABAS uses simple models implemented in the receiver software that are adequate for en route navigation through non-precision approach phases of flight, but are not adequate for any type of approach during which vertical guidance is provided. SBAS provides ionospheric delay corrections derived from measurements at a set of reference stations distributed over a wide area. GBAS provides corrections for the combined effects of various sources of ranging errors, including ionospheric delays. The corrections provided by SBAS and GBAS are much more accurate than those calculated by ABAS, because they are derived in real-time from actual measurements, and are therefore adequate for approach procedures with vertical guidance.

GNSS provides navigation either using unaugmented GNSS and RAIM or FDE, or using SBAS corrections. The availability and continuity of GNSS en route and NPA services are very robust against ionospheric delays caused by geomagnetic storms. This robustness is primarily due to the relatively wide alert limits associated with en route and non-precision approach operations.

SBAS augmentation makes APV possible by ensuring real-time monitoring of core constellation satellites and ionospheric delays. APV operations require accurate ionospheric corrections, as well as relatively narrow integrity bounds, and these bounds may be widened during periods when the ionosphere is severely disturbed, in order to account for the increased variability of ionospheric delays, while ensuring the integrity of the position solutions for all users. APV service is very robust in mid- and high-latitude regions, and losses of service due to ionospheric effects are expected to occur less than 1% of the time. Interruptions of APV service may occur during severe geomagnetic storms and affect portions of the service area for short periods of time. In rare cases, extremely severe geomagnetic storms may even cause temporary loss of APV service over large portions of the

SBAS service area for several hours. During pre-flight planning, pilots can consult Canadian Space Weather Forecast Centre products to determine if APV service for their flight may be affected. See: <www.spaceweather.gc.ca/index-en.php>.

5.6 INSTRUMENT FLIGHT RULES (IFR) FLIGHT PLAN EQUIPMENT SUFFIXES

On an instrument flight rules (IFR) flight plan, the letter “G” in Item 10 (equipment and capabilities) indicates that the aircraft has IFR-approved global positioning system (GPS) or wide area augmentation system (WAAS) avionics, and can therefore be cleared by air traffic service (ATS) on direct routings while en route, in terminal areas, and for global navigation satellite system (GNSS) based approaches.

5.7 AVIONICS DATABASES

Global navigation satellite system (GNSS) avionics used for instrument flight rules (IFR) flight require an electronic database that can be updated, normally on 28- or 56-day cycles. The updating service is usually purchased under subscription from avionics manufacturers or database suppliers.

Database errors do occur, and should be reported to the avionics database supplier. It is good practice to verify that retrieved data is correct, and it is mandatory to do so for approach data. Verification can be accomplished either by checking waypoint coordinates or by checking bearings and distances between waypoints against charts.

5.8 USE OF GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS) IN LIEU OF GROUND-BASED AIDS

See *AIP Canada* ENR 4.3.

5.9 AREA NAVIGATION (RNAV) APPROACHES AT ALTERNATE AERODROMES

Pilots may take credit for an area navigation (RNAV) approach at an alternate aerodrome as outlined in the *Canada Air Pilot (CAP)*.

Taking credit for RNAV approaches at an alternate aerodrome for instrument flight rules (IFR) flight plan filing purposes is possible because the availability of receiver autonomous integrity monitoring (RAIM) or wide area augmentation system (WAAS) integrity is normally very high. However, when satellites are out of service, availability could decrease. Consequently, it is necessary to determine satellite status to ensure that the necessary level of integrity will be available. The procedures for this are explained in the next two sections.

5.9.1 Global Navigation Satellite System (GNSS) Approaches—Global Positioning System (GPS) (TSO-C129/C129a) Avionics

The status of the GPS constellation may be obtained through the FAA by contacting a NAV CANADA FIC and requesting the international NOTAM file KGPS.

A procedure that meets the requirement to ensure that approach-level RAIM will be available for TSO-C129/C129a avionics is as follows.

- (a) Determine the ETA at the proposed aerodrome.
- (b) Check the GPS NOTAM file (KGPS) for a period of 60 min before and after the ETA. If not more than one satellite outage is predicted during that period, then this procedure is satisfied. If two or more satellites are anticipated to be unserviceable during the ETA ± 60 -min period, then it is necessary to determine if approach-level RAIM will be available, taking into account the reduced availability resulting from the outages. This may be accomplished by using commercially-available dispatch RAIM prediction software, acquiring a current almanac, and manually deselecting those satellites for the times described in the NOTAM.

The RAIM availability requirement is satisfied if the resulting prediction indicates that RAIM will be unavailable for a total of 15 min or less during the ETA ± 60 -min period.

It may be possible to change the alternate or adjust the departure time (and hence the ETA) and re-run the prediction to find a time for which the required RAIM availability is achieved, or simply to find a time when fewer than two satellite outages are predicted.

5.9.2 Global Navigation Satellite System (GNSS) Approaches—Wide Area Augmentation System (WAAS) Avionics

Operators using WAAS avionics (TSO-C145a/C146a) can verify that an approach is expected to be available by:

- (a) checking NOTAM that apply to the FIR to ensure that no widespread WAAS outages have occurred, and then
- (b) checking the WAAS horizontal and vertical service status, available at <https://www.nstb.tc.faa.gov/index.htm>, to predict if the desired approach line of minima is available given the current ionospheric conditions.

In the event of a widespread outage of WAAS, poor WAAS horizontal or vertical performance due to current ionospheric conditions, or an aerodrome outside the GEO coverage area, the pilot may need to determine if approach-level RAIM, as computed by a WAAS receiver, will be available. In this case, the pilot may use the procedure described in COM 5.9.1 for TSO-C129/C129a avionics. This will provide a safe, although conservative, indication of the availability of LNAV.

5.10 GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS) VULNERABILITY—INTERFERENCE AND ANOMALY REPORTING

Global navigation satellite systems (GNSS) are used in many applications: financial, security and tracking, transportation, agriculture, communications, weather prediction, scientific research, etc. Because it is used for such a wide range of civilian purposes, when somebody wishes to disable one GNSS-based system, their actions can also disrupt other, unrelated systems.

Jamming, directed at non-aviation users, could affect aircraft operations. Over the past few years, Innovation, Science and Economic Development Canada has encountered several cases of illegal importation, manufacturing, distribution, offering for sale, possession and use of radiocommunication jamming devices, all of which are prohibited under the *Radiocommunication Act*. Many jamming devices are manufactured for the purpose of disrupting the functioning of GNSS receivers, cellular networks and low-power communication devices, such as cordless telephones and Wi-Fi networks. Of primary concern is the proliferation of radiocommunication jammers designed to defeat vehicle tracking and fee-collecting systems. Depending on signal strength, these jammers can also prevent communication related to 9-1-1 and emergency services, while inadvertently and unknowingly, in most cases, inhibiting aircraft in the vicinity overhead from receiving GNSS signals.

In the event of suspected interference or other problems with GNSS, pilots should advise air traffic service (ATS), and, if necessary, revert to using traditional aids for navigation. Pilots are also requested to complete a GNSS Anomaly Report Form, available at <https://www.navcanada.ca/en/flight-planning/flight-planning-and-reporting.aspx/#b0c94be7e7554546ad8d85fa44fa7385>, or equivalent, in order to assist in the identification and elimination of sources of interference or degradation of the navigation signal.

5.11 PROPER USE OF GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS)

Global navigation satellite system (GNSS) offers a great opportunity to improve aviation safety and efficiency. Many pilots are benefiting from the advantages of GNSS as a principal navigation tool for instrument flight rules (IFR) flight or for visual flight rules (VFR) operations. To ensure safety, pilots must use GNSS properly. Here are some safety tips:

- (a) use only IFR-certified avionics for IFR flights because hand-held and panel-mount VFR do not provide the integrity needed for IFR operations;
- (b) for IFR flight, use a valid database for approach—a new one is required every 28 or 56 days;
- (c) verify that all procedures that could be required are present in the database prior to flight to remote or small aerodromes—data storage limitations have resulted in some manufactures omitting certain data from the avionics database;
- (d) do not become an approach designer—approach designers require special training and specific tools, and there are many levels of validation before an approach is commissioned. Furthermore, the receiver autonomous integrity monitoring (RAIM) level and course deviation indicator (CDI) sensitivity will not be appropriate if an approach is not retrieved from the avionics database;
- (e) never fly below published minimum altitudes while in instrument conditions. Accidents have resulted from pilots relying too much on the accuracy of GNSS;
- (f) use VFR GNSS receivers only to supplement map reading in visual conditions, not as a replacement for current charts;

- (g) position hand-held receivers and related cables carefully in the cockpit to avoid the potential for electromagnetic interference (EMI), and to avoid interfering with aircraft controls. Handheld units with valid databases could be useful in an emergency if IFR unit failed; and
- (h) resist the urge to fly into marginal weather when navigating VFR. The risk of becoming lost is small when using GNSS, but the risk of controlled flight into terrain (CFIT) increases in low visibility. VFR charts must also be current and updated from applicable NOTAMs, and should be the primary reference for avoiding alert areas, etc. Some VFR receivers display these areas, but there is no guarantee that the presentation is correct, because there is no standard for such depictions.

5.12 VHF OMNIDIRECTIONAL RANGE (VOR)/DISTANCE MEASURING EQUIPMENT (DME) (RHO-THETA) SYSTEM

The capability of on-board area navigation (RNAV) computer systems which utilize VHF omnidirectional range (VOR)/distance measuring equipment (DME) signals varies considerably. The computer electronically offsets a VOR/DME station to any desired location within reception range. The relocated position is known as a waypoint and is defined by its bearing and distance from the station. Waypoints are used to define route segments and the computer provides steering guidance to and from waypoints.

5.13 DISTANCE MEASURING EQUIPMENT (DME-DME [RHO-RHO]) SYSTEM

DME-DME is a system which combines distance measuring equipment (DME) receivers with a microprocessor to provide an area navigation (RNAV) capability. The system has the location of the DME facilities in its database. Measuring the distance from two or more of these stations can provide a positional fix. The system provides a means of entering waypoints for a random route and displays navigation information such as bearing, distance, cross-track error and time-to-go between two points.

6.0 PERFORMANCE-BASED NAVIGATION (PBN)

6.1 GENERAL

Performance-based navigation (PBN) is not a stand-alone concept. Rather, along with communications, surveillance, and air traffic management (ATM), it is one of the four strategic enablers that support an overall airspace concept. An airspace concept may be described as a master plan or vision for a particular section of airspace, which aims to improve safety, increase capacity and efficiency, and mitigate negative environmental impacts.

PBN is intended to enable more repeatable, reliable and predictable flight tracks as well as smaller route containment areas to increase operational efficiency. In the simplest form, it is area navigation (RNAV) based on performance requirements for

aircraft operating along an air traffic service (ATS) route, on an instrument approach procedure (IAP) or within designated airspace. Under the PBN concept, RNAV is defined as a method of navigation that permits aircraft operation on any desired flight path within the coverage of ground-based or space-based navigation aids (NAVAIDs) or within the limits of the capability of self-contained aids (inertial navigation). Area navigation systems can take two forms: RNAV, which is the basic definition above, or required navigation performance (RNP), which has an additional functional requirement for on-board performance monitoring and alerting. The RNP system relies upon the capability of the on-board navigation system to monitor, in real time, the achieved navigation performance and to alert the flight crew when the specified minimum performance appropriate to a particular operation cannot be met. This additional functionality provided by RNP allows the flight crew to intervene and take appropriate mitigation actions if necessary. On-board performance monitoring and alerting allows RNP operations to provide an additional level of safety and capability over RNAV operations.

All future RNAV will identify performance requirements through the use of navigation specifications rather than defining required equipment of specific navigation sensors (VHF omnidirectional range [VOR], automatic direction finder [ADF], etc.). These navigation specifications are expressed in terms of accuracy, integrity, availability, continuity, and functionality needed for the proposed operation.

Accuracy: In the context of PBN, accuracy is the capability of the navigation system to maintain the computed position within a specified distance (lateral navigation accuracy) of the actual position 95 percent of the time.

Integrity: Integrity is the level of confidence that can be placed in the information received from the navigation system. Normally defined as a percentage probability to satisfy the assurance condition (i.e. 10^{-5}), it includes the ability of an RNP system to provide timely and valid warnings to users when the system must not be used for the intended operation or phase of flight.

Availability: Availability is stated as a percentage of time the navigation system can perform its function. It should provide reliable navigation information and present it to the crew, autopilot or other system managing flight of the aircraft.

Continuity: Continuity refers to the ability of a navigation system to provide its service without interruption. It should do so with the specified level of accuracy and integrity throughout the intended period of operation, assuming that it was available at the start of the operation.

Functionality: A set of functions or capabilities associated with PBN operations. Examples could include course deviation scaling and radius to fix (RF) capability.

6.2 KEY ELEMENTS OF PERFORMANCE-BASED NAVIGATION (PBN)

Performance-based navigation (PBN) consists of three main elements: navigation aid (NAVAID) infrastructure, navigation specifications and navigation applications. These elements, described in detail further on, must be present to have a fully incorporated PBN concept.

6.2.1 Navigation Aid (NAVAID) Infrastructure

The NAVAID infrastructure that contributes to an RNAV system may consist of ground-based, space-based or on-board NAVAIDS that support or provide positioning capabilities. System types are as follows:

- (a) Ground infrastructure, which includes commissioned VORs and DMEs. (NDBs do not provide the specific range and azimuth information with accuracy necessary to be used in an RNAV system).
- (b) Authorized GNSS space-based infrastructure (satellite constellations) such as: GPS, the European Union’s Galileo, the Russian GLONASS, etc.
- (c) SBASs that correct for variance in the GNSS satellite signals in order to provide greater accuracy and/or signal quality, e.g. WAAS.
- (d) GNSS GBASs that provide navigation and precision approach service in the vicinity of the host airport, e.g. LAAS, GBAS landing system (GLS), etc.
- (e) Certified INS or inertial reference units (IRU), which support on-board capability.

6.2.2 Navigation Specifications

A navigation specification is used as the basis for airworthiness and operational approval. It details the performance required of an RNAV or RNP system in terms of accuracy, integrity, availability, continuity, required navigation functionalities and NAVAIDS, and any requirements placed on the flight crew. Having a published navigation specification on Canadian routes and procedures will ensure compliance with common aircraft equipment and training that will result in assurance of track conformance. There are two main types of navigation specifications: RNAV and RNP.

An RNAV specification is based on an RNAV system and would be denoted by RNAV(X). An RNP navigation specification is based on an RNP system and is denoted by RNP(X).

In the examples above, “(X)” indicates the lateral navigation accuracy, in nautical miles, to be maintained 95 percent of the flight time by the population of aircraft operating within the airspace, route or procedure. For RNP specifications, it is also possible to have advanced RNP (A-RNP) and approach navigation specifications that cover all segments of an instrument approach. They are denoted as RNP APCH (RNP approach) or RNP AR APCH (RNP authorization required approach).

A navigation specification identifies not only a lateral accuracy figure but also functional and aircrew requirements. Therefore, certification for one type of navigation specification does not imply automatic qualification for a less stringent specification, and an RNP specification doesn’t necessarily enable an RNAV specification.

ICAO has developed guidance on a range of navigation specifications. It is the responsibility of each State to determine which navigation specifications would be most applicable within their airspace concept with regards to current regulations and NAVAID infrastructure. For this reason it is important to note

that what is needed to meet a navigation specification in one State may vary from that of another.

The following chart depicts all of the navigation specifications and their intended operational domain as outlined in ICAO’s *Performance-based Navigation (PBN) Manual* (Doc 9613).

Table 6.1—Navigation Specification Designations

| RNAV Specifications | | RNP Specifications | |
|--|---|--|--|
| Oceanic and Remote Navigation Applications | En route and Terminal Navigation Applications | Oceanic and Remote Navigation Applications | En route and Terminal Navigation Applications |
| RNAV 10* | RNAV 5 RNAV 2 RNAV 1 | RNP 4 RNP 2 | RNP 2 RNP 1 A-RNP RNP APCH RNP AR APCH RNP 0.3 |
| *Formerly referred to as RNP 10 | | | |

6.2.3 Navigation Application

Navigation application is the application of a navigation specification and supporting NAVAID infrastructure to specific routes, procedures and/or defined airspace volumes.

6.3 NAVIGATION SPECIFICATIONS EXPANDED

6.3.1 Area Navigation (RNAV) 10

RNAV 10 was historically designated as RNP 10. It requires aircraft be equipped with at least two independent long range navigation systems; any combination of INS/inertial reference unit (IRU) or GNSS meet the RNAV 10 requirements. During operations in airspace or on routes designated as RNAV 10, the lateral total system error must also be within ±10 NM for at least 95 percent of the total flight time. For normal operations, cross-track error/deviation should be limited to plus or minus one-half of the navigation accuracy associated with the route (i.e. 5 NM). Brief deviations from this standard (e.g. overshoots or undershoots) are allowable during and immediately after route turns, up to a maximum of one times the navigation (i.e. 10 NM).

Canadian RNAV 10 operations requirements are defined in AC 700-006—*Required Navigation Performance 4 (RNP 4) and Required Navigation Performance 10 (RNP 10) Airspace* and the associated Special Authorization RNP 10.



6.3.2 Area Navigation (RNAV) 5

RNAV 5 is an en route navigation specification and may also be used for initial STAR or ending SID segments, where the leg segments are beyond 30 NM from an aerodrome. RNAV 5 operations are based on the use of RNAV equipment that automatically determines aircraft position in the horizontal plane using inputs from one or a combination of the following types of position sensors:

- (a) VOR/DME
- (b) DME/DME
- (c) INS or IRS
- (d) GNSS

VOR/DME- and DME/DME-based RNAV 5 have limited opportunities in Canadian airspace because of the required numbers and geometry of ground-based aids to provide robust infrastructure. Introduction of RNAV 5 in Canadian airspace applications is of low value since current RNP-C airspace requirements already require performance that exceeds RNAV 5 when conducting RNAV.

Operational requirements are defined in AC 700-015—*En Route Area Navigation Operations RNAV 5 (Formerly B-RNAV)* and the associated Special Authorization RNAV 5.

6.3.3 Area Navigation (RNAV) 1 and RNAV 2

RNAV 1 and RNAV 2 operations are based on the use of the same aircraft receivers as those required for RNAV 5. Additional aircraft functionality and NAVAID infrastructure requirements are needed to meet the more demanding performance of RNAV 1 and RNAV 2. This navigation specification is applicable to all routes, inside or outside of controlled airspace, SIDs and STARs. It also applies to IAP leg segments up to the FAF. RNAV 1 and RNAV 2 routes are expected to be conducted in a surveillance environment with DCPC. In Canada, RNAV 1 has some potential for terminal RNAV use for SIDs and STARs in areas where multiple DME pairs are available.

Operational requirements are defined in AC 700-019—*Terminal and En Route Area Navigation Operations (RNAV 1 and 2)* and the associated Special Authorization RNAV 1 and RNAV 2.

6.3.4 Required Navigation Performance (RNP) 4

RNP 4 is intended for oceanic or remote airspace where a robust ground-based navigation infrastructure is not available. Aircraft must have at least two fully serviceable independent long range navigation systems (LRNS) listed in the flight manual; both must be operational at the point of entry into RNP 4 airspace. Position integrity bounding can currently only be met using certified GNSS receivers. The GNSS receivers may be part of a stand-alone navigation system or one of the sensors in a multi-sensor system. Where GNSS is an input as part of a multi-sensor system, the aircraft's position source must use GNSS positions exclusively during RNP 4 operations.

Canadian operational requirements are defined in AC 700-006—*Required Navigation Performance 4 (RNP 4) and Required Navigation Performance 10 (RNP 10) Airspace* and the associated Special Authorization RNP 4.

6.3.5 Required Navigation Performance (RNP) 2

RNP 2 is intended for en route application, primarily in areas where there is sparse or no ground NAVAID infrastructure, limited or no ATS surveillance, and low- to medium-density traffic. Use of RNP 2 in continental applications requires a lower continuity requirement than use in oceanic or remote applications. In oceanic or remote applications, the target traffic is primarily transport category aircraft operating at high altitude, whereas continental applications may include a significant percentage of other aircraft.

RNP 2 requires the use of certified GNSS receivers. Operators are required to have the means to predict the availability of GNSS fault detection (e.g. ABAS RAIM) to support operations along an RNP 2 route. The *AIP Canada* will indicate when a prediction capability is required and an acceptable means to satisfy that requirement.

Operational requirements for RNP 2 (Continental) are defined in AC 700-38—*Performance-based Navigation (PBN) — EnRoute* and the associated Special Authorization RNP 2 (Continental). RNP 2 (Oceanic/Remote) has additional requirements over those for RNP 2 Continental, but they have not yet been defined in a Canadian AC. A separate AC will be published when RNP 2 (Oceanic/Remote) operations are implemented in Canadian-controlled airspace.

6.3.6 Required Navigation Performance (RNP) 1

The RNP 1 navigation specification is intended to be applied on SIDs and STARs within 30 NM of the aerodrome where the surveillance services are limited or do not exist and/or a ground-based RNAV infrastructure is not practical. The STARs provide a means to connect the en route structure to a variety of approach procedures, including RNP approach (RNP APCH), RNP authorization required approach (RNP AR APCH) and ILS. Application of RNP 1 enables the use of RF leg segments in applications such as the STAR, transition to the approach or approach initial segments.

Position integrity bounding for RNP 1 can currently only be met using certified GNSS receivers. The GNSS receivers may be a part of a stand-alone navigation system or one of the sensors in a multi-sensor system. Where GNSS is an input as part of a multi-sensor system, the aircraft's position source must use GNSS positions exclusively during RNP 1 operations. During operations in airspace or on routes designated as RNP 1, the lateral total system error must be within ± 1 NM for 95 percent of the total flight time. For normal operations, cross-track error/deviation should be limited to plus or minus one half of the navigation accuracy associated with the procedure. Brief deviations from this standard during and immediately after turns, up to a maximum of one times the navigation accuracy are allowable.

For RNP 1 routes, pilots must use a lateral deviation indicator, flight director, or autopilot in lateral navigation mode. Pilots of aircraft with a lateral deviation display must ensure that lateral deviation scaling is suitable for the navigation accuracy associated with the route/procedure.

Canadian RNP 1 operational requirements are defined in AC 700-025—*Required Navigation Performance 1 (RNP 1)* and the associated Special Authorization RNP 1.

6.3.7 Required Navigation Performance (RNP) 0.3

RNP 0.3 was developed in response to the helicopter community's desire for narrower IFR obstacle-free areas to allow operations in obstacle-rich environments and to allow simultaneous, non-interfering operations in dense terminal airspace. While this specification has been defined primarily for helicopter applications, it does not exclude the application to fixed-wing operations where demonstrated performance is sufficient to meet the functional and accuracy requirements of this specification for all phases of flight.

This specification requires the use of certified GNSS receivers; its implementation is not dependent on the availability of SBAS. DME/DME-based RNAV systems are not capable of consistently providing RNP 0.3 performance, and RNP 0.3 operations through application of DME/DME-based navigation is not currently viable. Operators are required to have the means to predict the availability of GNSS fault detection (e.g. RAIM) to support RNP 0.3 operations. The on-board RNP system, GNSS avionics, air navigation service provider (ANSP) or other entities may provide a prediction capability. The *AIP Canada* will indicate when a prediction capability is required and an acceptable means to satisfy that requirement. Owing to the high availability of RNP 0.3 performance available to SBAS receivers, prediction will not be required where the navigation equipment can make use of SBAS augmentation and the planned operation will be contained within the service volume of the SBAS signal.

Operational requirements are currently defined in ICAO's *Performance-based Navigation (PBN) Manual* (Doc 9613), Volume II, Part C, Chapter 7, but have not yet been defined in a Canadian AC; therefore, no Special Authorization is available.

6.3.8 Advanced Required Navigation Performance (A-RNP)

This is the only navigation specification that enables operations under other associated navigation specifications. When advanced RNP (A-RNP) is certified, the following other navigation accuracy and functional requirements are met in navigation specifications: RNAV 5, RNAV 2, RNAV 1, RNP 2, RNP 1, and RNP APCH. Some other functional elements are optional, such as RNP scalability, higher continuity, FRT, and baro-VNAV. However, RF leg capabilities are a requirement.

A-RNP has a very broad operational application; for operation in oceanic or remote airspace, on the continental en route structure, as well as on arrival and departure routes and approaches. Operations would rely solely on the integrity of the RNP system without a reversionary capability to conventional means of navigation since a conventional infrastructure may not be available. The advantage of utilizing a designation of A-RNP for a flight operation is the combined performance and functionality of a range of navigation specifications encompassing all phases of flight.

For further information on A-RNP, refer to ICAO's *Performance-based Navigation (PBN) Manual* (Doc 9613), Volume II, Part C, Chapter 4. Canadian operational approval of A-RNP is not currently in place; therefore, no AC or Special Authorization has been issued.

6.3.9 Required Navigation Performance Approach (RNP APCH)

RNP approach (RNP APCH) is the ICAO navigation specification designation for procedures currently published in Canada as "RNAV (GNSS)" and authorized under Special Authorization RNP APCH. They include approach operations with minima designated as "LNAV", "LNAV/VNAV", "LP" and "LPV".

Currently, integrity bounding for an RNP APCH can only be met using certified GNSS receivers. The GNSS receivers may be part of a stand-alone navigation system or one of the sensors in a multi-sensor system.

Canadian-specific RNP APCH requirements are published in AC 700-023—*Required Navigation Performance Approach (RNP APCH)* and the associated Special Authorization RNP APCH.

6.3.10 Required Navigation Performance Authorization Required Approach (RNP AR APCH)

RNP authorization required approach (RNP AR APCH) procedures can be built with various levels of RNP lateral containment values on the initial, intermediate, final and missed approach segments. There are increasingly demanding aircraft certifications and operational approvals required when RNP values lower than 0.3 NM are applied in any of the segments. These approaches will be published in pertinent publications as "RNAV (RNP)".

As with all the other RNP navigation specifications, RNP AR APCH position integrity bounding can only be met by utilizing certified GNSS receivers. There are numerous other aircraft equipment and functional requirements needed to meet the more demanding performance requirements. They can be found in AC 700-024—*Required Navigation Performance Authorization Required Approach (RNP AR APCH)* and Special Authorization RNP AR APCH.

6.4 FIXED RADIUS PATHS

Typically, with conventional navigation, turns had a large range of dispersion (some aircraft turned tight, others had wider turns) depending on aircraft speed, turn anticipation, bank angle and roll rate. Fixed radius paths standardize turns and provide a predictable, repeatable and accurate ground track throughout a turn. Using required navigation performance (RNP), aircraft can have a smaller area of containment throughout a turn, allowing greater flexibility to design procedures that avoid terrain, noise sensitive areas, restricted airspace or other arrival paths to nearby airports in a complex airspace structure. There are two types of fixed radius paths that may be used: radius to fix (RF) path terminator and fixed radius transitions (FRT).

While complex flight paths can now be designed and displayed as the active route, the aircraft must have the capability to accurately follow the defined path. Pilots are familiar with flying turns at a constant airspeed and angle of bank which enables a circular flight path to be flown with reference to the air mass and are trained to manually compensate for the presence of wind if necessary. Pilots now need to understand that the RNP system will fly an exact circular flight path over the ground. Groundspeed and the angle of bank must be adjusted throughout the turn by the automatic flight control system to maintain that circular flight path and in some cases these may be limiting factors for maintaining the specified turn radius.

6.4.1 Radius To Fix (RF) Path Terminator

The RF path terminator, referred to as an RF leg, is a specific fixed-radius curved path in a terminal or approach procedure. An RF leg is defined by a constant radius originating from the centre fix, the arc starting fix, the arc ending fix, and the turn direction. Only RNP systems are capable of flying RF legs, by providing precise and positive course guidance along a curved track, with the same containment value that would be achieved in a straight leg segment. In addition, the distance travelled from beginning to end of the turn will remain constant for every aircraft. This allows longitudinal separation to be maintained throughout the turn for aircraft travelling at the same speed.

Operational approval to use RF legs in conjunction with other RNP navigation specifications can be found in AC 700-027—*Radius to Fix (RF) Path Terminator* and Special Authorization RF Leg. Additional authorization is not required for RNP AR APCH or A-RNP as RF capability is already mandatory in these two Special Authorizations.

6.4.2 Fixed Radius Transition (FRT)

An FRT is used as an enabler to apply closer route spacing along turns in the en route structure. An FRT is intended to define the transition between airways where separation is required in the turns. Having smaller containment areas in turns allows for higher traffic density with closer spaced routes. The RNP system supporting FRT is capable of providing the same track-keeping accuracy in the turn as in the straight line segment. An RNP system seamlessly joins associated route segments.

Operational approval is not currently available in Canada. For further information on FRTs, refer to ICAO's *Performance-based Navigation (PBN) Manual* (Doc 9613), Volume II, Part C, Appendix 2.

6.5 INTERNATIONAL CIVIL AVIATION ORGANIZATION (ICAO) FLIGHT PLAN COMPLETION

Pilots should review the planned route of flight to determine that area navigation (RNAV)/required navigation performance (RNP) requirements, the aircraft, and the operator are approved for the desired route. Performance-based navigation (PBN) compliant aircraft should enter the appropriate equipment code in Item 10 of the International Civil Aviation Organization (ICAO) flight plan. A corresponding indication of RNAV and/or RNP capabilities must be entered in Item 18.

6.6 NAVIGATION ERROR COMPONENTS

The inability to achieve the required lateral navigation accuracy may be due to navigation errors related to aircraft tracking and positioning. These errors produce a path that is offset horizontally from the desired path. The following are sources of error for area navigation (RNAV) systems:

Where:

- Desired path is the path over the ground that the aircraft is expected to fly.
- Defined path is the reference path computed by the flight plan management function of the RNAV system.
- Estimated position is provided by the navigation function of the RNAV system.
- True position is the aircraft's actual position over the ground.

Path definition error (PDE): The difference between desired and defined paths which reflects errors in the navigation database, computational errors in the RNAV system and display errors. PDE is usually very small and often assumed to be negligible.

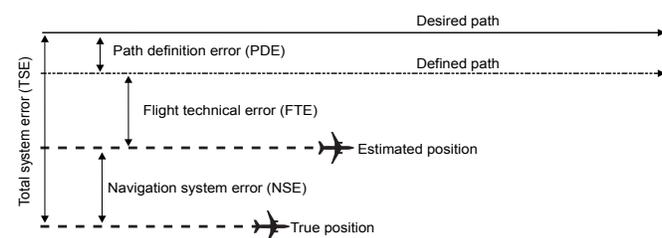
Flight technical error (FTE): The difference between estimated position and defined path. It relates to the ability of an air crew or autopilot to fly along a defined path. Any display errors, such as a course deviation indicator (CDI) centering error, may cause FTE. FTE is usually the largest error component of the total system error (TSE).

Navigation system error (NSE): The difference between true and estimated position. The NSE is defined during navigation system certification.

TSE: The difference between true position and desired position. This error is equal to the sum of the vectors of the PDE, FTE and NSE.

Any of the errors mentioned above would affect the ability of the aircraft to meet the required lateral navigation accuracy. If the on-board performance monitoring system cannot guarantee, with sufficient integrity, that the position meets the RNP defined in a navigation specification, an alert will be issued to the crew.

Figure 6.1—Lateral Navigation Errors



7.0 SURVEILLANCE

Surveillance enables air traffic control (ATC) to increase airspace use by allowing a reduction in aircraft-to-aircraft and aircraft-to-obstacle separation. In addition, surveillance permits an expansion of flight information services such as traffic information and navigation assistance. There are four types of surveillance systems currently used by ATC: primary surveillance radar (PSR), secondary surveillance radar (SSR), automatic dependent surveillance - broadcast (ADS-B) and multilateration (MLAT).

7.1 PRIMARY SURVEILLANCE RADAR (PSR)

Primary surveillance radar (PSR) computes target positions by determining the range and azimuth of transmitted and reflected radio frequency energy. It is a passive surveillance system and therefore does not rely on information transmitted from the aircraft.

Primary radar is used in the following applications:

- Terminal surveillance radar (TSR)*—In general, a short-range PSR (80 NM) operating on 1 250 to 1 350 MHz complements secondary surveillance radar (SSR) for terminal operations.
- Precision approach radar (PAR)*—A high-definition, short-range PSR operating on 9 000 to 9 180 MHz and is used as an approach aid. PAR provides the controller with altitude, azimuth and range information of high accuracy to assist pilots in executing approaches. While PAR is mainly a military system, it is available at some civilian airports and may be used by civilian pilots. Civil aircraft approach limits are published in the *Canada Air Pilot (CAP)* and the *Restricted Canada Air Pilot (RCAP)*.
- Airport surface detection equipment (ASDE)*—Surveillance of surface traffic is provided at airports where traffic warrants it. ASDE is a high-definition PSR operating on 16 GHz. Tower controllers use ASDE to monitor the position of aircraft and vehicles on the manoeuvring areas of the airport (runways and taxiways), particularly during conditions of reduced visibility.
- Weather radar*—Weather radar is a PSR used by the Meteorological Service of Canada to monitor for hazardous weather conditions.

For a map of PSR coverage in Canada, see *AIP Canada* ENR 1.6, Figure 1.6.1, Primary Radar Coverage.

7.2 SECONDARY SURVEILLANCE RADAR (SSR)

Secondary surveillance radar (SSR) determines aircraft range by measuring the interval between transmitting an interrogation to and receiving a reply from an airborne transponder.

SSR is a cooperative surveillance system and does not provide a position for an aircraft without an operating transponder. SSR offers significant operational advantages to air traffic control (ATC), such as increased range, positive identification and aircraft altitude, when the aircraft has an altitude-encoding transponder.

SSR is used in the following applications:

- En route control*—SSR is a long-range radar with a range of 200 NM or more. It transmits on 1 030 MHz and receives the transponder reply on 1 090 MHz. SSR is the main source of en route (airway/area navigation [RNAV] route) surveillance and is not normally combined with primary surveillance radar (PSR).
- Terminal control*—Terminal surveillance radar (TSR) uses long-range SSR equipment similar to en route control and may be used in conjunction with a short-range PSR.

For a map of SSR coverage in Canada, see *AIP Canada* ENR 1.6, Figure 1.6.2, Secondary Surveillance Radar Coverage.

7.2.1 Code Assignment

In the CFS and the CWAS, Section B, “Aerodrome/Facility Directory”, the table for an aerodrome may have a subheading PRO, which may contain information on special procedures for code assignment established at the aerodrome.

7.3 AUTOMATIC DEPENDENT SURVEILLANCE - BROADCAST (ADS-B)

Automatic dependent surveillance - broadcast (ADS-B) is a surveillance technology that gives controllers the opportunity to provide radar-like services. It uses aircraft avionics, satellites and/or ground infrastructure to relay a range of aircraft parameters to air traffic control (ATC). The system is automatic since no external stimulus is required for operation, and dependent because it relies on aircraft avionics to provide surveillance services through broadcast messages.

NAV CANADA’s ADS-B ground infrastructure consists of ground receiver stations, target processors and situation displays. The ground stations receive ADS-B signals and transfer the data via land line or satellite link to the target processors located within an area control centre (ACC). Target processors build a track profile based on the aircraft’s unique International Civil Aviation Organization (ICAO) 24-bit identifier. This profile is presented to ATC on a situation display to enable surveillance separation services.

For a map of ADS-B coverage in Canada, see *AIP Canada* ENR 1.6, Figure 1.6.3, Automatic Dependent Surveillance - Broadcast Coverage.

7.3.1 Aircraft Equipment

On-board aircraft equipment is responsible for gathering a range of flight parameters and compiling them into the ADS-B message, which is then transmitted through the Mode S transponder on a 1 090 MHz extended squitter (1 090ES). The full range of data is transmitted once per second, allowing ATC to access real-time aircraft position information.

At a minimum, the following aircraft parameters must be broadcast:

- Airborne position*—Position data is generated by a GPS receiver compliant with TSO-C129, TSO-C145 or TSO-C146. A high degree of reliance is placed on the GPS data as it is

the basis for reduced traffic separation. Therefore, it must be capable of producing a HPL.

- (b) *Pressure altitude*—This is provided by the on-board encoding altimeter.
- (c) *Aircraft identity*—Each Mode S transponder has a unique address assigned by the State of aircraft registry and known as the ICAO 24-bit aircraft identifier. It is entered into the transponder at the time of installation and cannot be modified by pilots from the flight deck. This address is used for aircraft identification and track processing.
- (d) *Flight identification (Flight ID)*—A four- to seven-character alphanumeric parameter usually entered by the pilot into the transponder control panel (if present) or FMS. A flight ID that is an exact replica of the aircraft identification entered in Item 7 of the ICAO flight plan must be programmed into the transponder or FMS in order to receive ATS surveillance services. It is important that the flight crew verify that the flight ID is correct prior to departure as some avionics prevent a change to the flight ID once airborne. Airline aircraft will use the three-letter ICAO airline code.

The flight ID has a seven-character maximum and can be either:

- (i) the aircraft registration mark (CGSCX, N6891DE, 90HYT); or
- (ii) the ICAO airline designator followed by the flight number (ACA020, WJA229, JZA8249).

Errors and discrepancies can arise during flight ID entry due to confusion over the correct format. Common errors that arise when entering the flight ID include the use of leading zeros, hyphens, dashes, spaces or failure to use the correct airline designator. Zeros only appear when they are part of the ICAO flight plan number as in the example below:

Generic Airlines Flight 371
 Generic Airlines ICAO assigned registration: GNA
 Flight number: 371
 On the ICAO flight plan it is entered as: GNA0371

The flight ID pilot input would be: G N A 0 3 7 1, not G N A 3 7 1 or G N A 3 7 1 0

- (e) *NUCp or NIC*—Numerical values that identify the quality of horizontal position data. The GNSS avionics is responsible for calculating either of these values by using the RAIM algorithm. These values equate to an Rc, which represents the uncertainty of the given position data in NM. Typical NUCp and NIC values range from 0–9 and 0–11 respectively. They are dynamic since the GPS constellation is constantly changing. Any detection of poor satellite geometry diminishes position data integrity, resulting in a reduction of NUCp or NIC values and a corresponding increase in Rc. NAV CANADA will accept position data contained in an ADS-B message with a NUCp value as low as 5 or a NIC as low as 6. Should the NUCp or NIC value fall below the minima, the target will not be passed through to ATC as a valid surveillance target.

- (f) *NACp*—A position quality indicator used by surveillance services to determine if the reported horizontal position meets an acceptable level of accuracy for the intended operation.

If an updated NACp has not been received within the past two seconds, the NACp value will be encoded as zero indicating “unknown accuracy” and will not be used for surveillance services.

- (g) *SIL*—Indicates the probability of the reported horizontal position exceeding the containment radius defined by the NIC. Should NAV CANADA receive a SIL value below the pre-selected minima, the target will not be passed through to ATC as a valid surveillance target.
- (h) *SPI*—A feature used to positively identify an aircraft. It is identical to the “Squawk Ident” feature on a basic transponder.
- (i) *Emergency status*—Activation of an emergency transponder code (7500, 7600 or 7700) will result in a common emergency signal being sent as part of an ADS-B message. If an emergency transponder code is activated, ATS will receive a generic emergency (EMR) indication on their display and may request further information from the flight crew regarding the nature of the emergency.

NOTE:

Flight ID, SPI and emergency status are the only elements that can be modified by the flight crew.

7.3.2 International Civil Aviation Organization (ICAO) Flight Plan Completion

ADS-B capable aircraft should enter the appropriate equipment code in Item 10 of the ICAO flight plan.

7.3.3 Airworthiness Compliance Requirements

Any aircraft that emits position information using a 1 090 MHz extended squitter (1 090ES) may be provided surveillance separation services, if they meet the airworthiness compliance requirements defined in *AIP Canada* ENR 1.6.

7.3.4 Surveillance Phraseology

Flight through ADS-B airspace is very similar to radar surveillance airspace with regard to common radio communication phraseology. However, pilots will not be advised when transitioning between ADS-B surveillance airspace and a radar coverage area. Common radar and surveillance phrases are listed below.

Table 7.1—Surveillance Phraseology

| Radar Phraseology | Surveillance Phraseology |
|--|---|
| RADAR SERVICE TERMINATED (non-radar routing if required). | SURVEILLANCE SERVICE TERMINATED (routing if required). |
| RADAR SERVICE TERMINATED DUE TO (reason). | SURVEILLANCE SERVICE TERMINATED DUE TO (reason). |
| SECONDARY RADAR OUT OF SERVICE. | ADS-B SURVEILLANCE OUT OF SERVICE DUE TO (reason). |
| MODE CHARLIE NOT VALIDATED. | PRESSURE ALTITUDE NOT VALIDATED. |
| MODE CHARLIE IS INVALID. | PRESSURE ALTITUDE IS INVALID. |
| RADAR SERVICE TERMINATED. RESUME POSITION REPORTS. | SURVEILLANCE SERVICE TERMINATED. RESUME POSITION REPORTS. |
| (aircraft ident) RADAR IDENTIFIED (position if required). | (aircraft ident) IDENTIFIED (position if required). |
| (aircraft ident) RADAR IDENTIFICATION LOST. | (aircraft ident) IDENTIFICATION LOST. |
| | IF ABLE, CHANGE YOUR FLIGHT ID TO (flight ID). |
| IF YOU READ (appropriate instructions), then — (action) OBSERVED. WILL CONTINUE RADAR CONTROL. | IF YOU READ (appropriate instructions), then — (action) OBSERVED. WILL CONTINUE SURVEILLANCE CONTROL. |
| | (aircraft ident) READING YOU ON SEVEN SEVEN ZERO ZERO. |
| | CONFIRM THE NATURE OF YOUR EMERGENCY. |

COM

7.4 MULTILATERATION (MLAT)

Multilateration (MLAT) increases air traffic service (ATS) situational awareness of aircraft and vehicles on the ground allowing them to safely manage ground movements, including in low visibility operations, by providing full surveillance coverage of runways, taxiways and terminal apron areas. MLAT uses a system of strategically placed ground stations to send interrogations and receive replies from Mode A, C or S transponders. It functions on a principle known as time difference of arrival (TDOA), where the system calculates the difference in transponder response time at multiple ground receivers and compares the results to determine a position. Usually three receiving units are required to obtain a horizontal position.

7.4.1 Code Assignment

In the CFS and the CWAS, Section B, “Aerodrome/Facility Directory”, the table for an aerodrome may have a subheading PRO, which may contain information on special procedures for code assignment established at the aerodrome.

Aircraft that have a technical limitation that might inhibit the transmission of a transponder code (such as weight on wheels switch deactivation) must report this condition to ATS and obtain an APREQ before commencing ground operations.

8.0 TRANSPONDER OPERATION

8.1 GENERAL

Transponders substantially increase the capability of ATS surveillance to detect aircraft. The use of automatic pressure altitude reporting equipment (Mode C) enables controllers to quickly determine where potential conflicts could occur. Proper transponder operating procedures and techniques provide both visual flight rules (VFR) and instrument flight rules (IFR) aircraft with a higher degree of safety. In addition, proper use of transponders with Mode C capability results in reduced communications and more efficient service.

When pilots receive air traffic control (ATC) instructions concerning transponder operation, they shall operate transponders as directed until they receive further instructions or until the aircraft has landed, except in an emergency, communication failure or act of unlawful interference.

ATC surveillance units are equipped with alarm systems that respond when an aircraft is within ATS surveillance coverage and the pilot selects the emergency, communication failure, or act of unlawful interference transponder code. It is possible to unintentionally select these codes momentarily when changing the transponder code. To prevent unnecessary alarm activation, pilots should avoid inadvertent selection of 7500, 7600 or 7700 when changing the code if either of the first two digits to be selected is a seven. For example, when changing from Code 1700 to Code 7100, first change to Code 1100 (and NOT Code 7700) and then change to Code 7100. Do not select STANDBY while changing codes as this will cause the target to be lost on the ATS surveillance situation display.

Pilots should adjust transponders to STANDBY while taxiing for takeoff, to ON (or NORMAL) as late as practicable before takeoff, and to STANDBY or OFF as soon as practicable after landing. In practice, transponders should be turned on only upon entering the active runway for departure and turned off as soon as the aircraft exits the runway after landing. Some airports have implemented surface surveillance services using multilateration (MLAT). MLAT relies on transponder returns; therefore, pilots of transponder-equipped aircraft should leave their transponders in the transmit mode at all times when on the manoeuvring area. Pilots should ensure that the transponder code issued by ATC is selected before switching the transponder out of STANDBY. In the event that no code has been issued by ATC, transponder Code 1000 should be selected.

In the event of a transponder or automatic pressure altitude reporting equipment (Mode C) failure during a flight when its use is mandatory, an aircraft may be operated to the next airport of intended landing; it may, thereafter, complete an itinerary or go to a repair base, if authorized by ATC.

ATC may, upon receiving a written request, authorize an aircraft not equipped with a functioning transponder or Mode C to operate in airspace where its use is mandatory. The purpose of this advanced request is to enable ATC to determine if the operation of the aircraft can be handled in the airspace at the time requested without compromising the safety of air traffic. Approval may be subject to conditions and limitations deemed necessary to preserve safety. Pilots must obtain approval before entering airspace where it is mandatory to be equipped with a functioning transponder and automatic pressure altitude reporting equipment. This includes aircraft proposing to take off from an airport located within that airspace.

8.2 TRANSPONDER REQUIREMENTS

CAR 605.35 outlines the transponder operating rule, as well as the circumstance in which operation with an unserviceable transponder is permitted. It also outlines the procedures to follow in order to operate an aircraft without a transponder and automatic pressure altitude reporting equipment within transponder airspace. CAR 601.03 states that “transponder airspace consists of:

- (a) all Class A, B and C airspace as specified in the *Designated Airspace Handbook*; and
- (b) any Class D or E airspace specified as transponder airspace in the *Designated Airspace Handbook*.”

This includes all Class E airspace extending from 10 000 ft above sea level (ASL) up to and including 12 500 ft ASL within radar coverage, as shown in Figure 8.1.

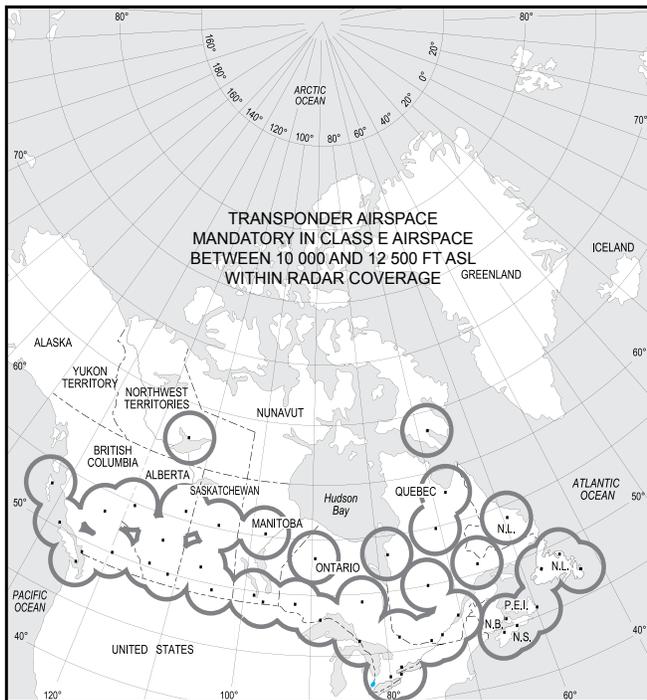
Pilots of instrument flight rules (IFR) aircraft operating within controlled or uncontrolled high-level airspace should adjust their transponder to reply on Mode A, Code 2000 and on Mode C, unless otherwise instructed by air traffic control (ATC).

NOTE:

Pilots instructed to squawk a discrete code should not adjust their assigned transponder code when informed that ATS surveillance is terminated. The termination of ATS surveillance

service does not necessarily constitute direction to change to Code 2000.

Figure 8.1—Transponder Airspace



8.3 INSTRUMENT FLIGHT RULES (IFR) OPERATIONS IN OTHER LOW-LEVEL AIRSPACE

During instrument flight rules (IFR) flight in controlled low-level airspace other than that described earlier, adjust the transponder to reply on Mode A, Code 1000, and on Mode C (if available), unless otherwise instructed by air traffic control (ATC). If an IFR flight plan is cancelled or changed to a visual flight rules (VFR) flight plan, the transponder should be adjusted to reply on the appropriate VFR code, as specified in the following paragraphs, unless otherwise instructed by ATC.

To enhance the safety of IFR flight in uncontrolled low-level airspace, pilots are encouraged to adjust their transponders to reply on Mode A, Code 1000 and Mode C (if available), unless otherwise instructed by ATC.

8.4 VISUAL FLIGHT RULES (VFR) OPERATIONS

During visual flight rules (VFR) flight in low-level airspace, the pilot should adjust the transponder to reply on the following unless otherwise assigned by an air traffic services (ATS) unit:

- Mode A, Code 1200 for operation at or below 12 500 ft above sea level (ASL); or
- Mode A, Code 1400 for operation above 12 500 ft ASL.

Upon leaving the confines of an airspace for which a special code assignment has been received, the pilot is responsible for changing to the code shown in (a) or (b), unless they are assigned a new code by an ATS unit.

NOTES:

- When climbing above 12 500 ft ASL, a VFR pilot should select Code 1200 until departure from 12 500 ft ASL at which point Code 1400 should be selected. When descending from above 12 500 ft ASL, a VFR pilot should select Code 1200 upon reaching 12 500 ft ASL. Pilots of aircraft equipped with a transponder capable of Mode C automatic altitude reporting should adjust their transponder to reply on Mode C when operating in Canadian airspace unless otherwise assigned by an ATS unit.
- Pilots of gliders that are equipped with a transponder should adjust the transponder to reply on Mode A, Code 1202 at all times, unless otherwise directed by air traffic control (ATC). If their transponder is capable, pilots should use Mode C as well.

8.5 PHRASEOLOGY

Air traffic services (ATS) personnel will use the following phraseology when referring to transponder operation.

SQUAWK (code)—Operate transponder on designated code in Mode A.

SQUAWK IDENT—Engage the identification (IDENT) feature of the transponder.

NOTE:

A pilot should operate the IDENT feature only when requested by an ATS unit.

SQUAWK MODE CHARLIE—Activate Mode C with automatic altitude reporting.

STOP SQUAWK MODE CHARLIE—Turn off automatic altitude reporting function.

RESET TRANSPONDER—Reset the transponder and transmit the SQUAWK (code) currently assigned. This phraseology may be used if the target or identity tag data is not being displayed as expected.

REPORT YOUR ALTITUDE—This phraseology may be used when it is necessary to validate altitude readouts by comparing the readout value with the altitude reported by the aircraft. An altitude readout is considered valid if the readout value does not differ from the aircraft-reported altitude by more than 200 ft; it is considered invalid if the difference is 300 ft or more.

NOTE:

Readout values are displayed in 100-ft increments.

SQUAWK STANDBY – SQUAWK (code)—The present position symbol (PPS) disappears or changes to a primary surveillance radar (PSR) symbol after the aircraft is instructed to change its transponder to STANDBY; the PPS reappears or changes back to a secondary surveillance radar (SSR) symbol after the aircraft is requested to return the transponder to normal operation.

8.6 EMERGENCIES

In the event of an emergency and if unable to establish communication immediately with an air traffic control (ATC) unit, a pilot wishing to alert ATC to the emergency situation should adjust the transponder to reply on Code 7700. Thereafter, communication should be established with ATC as soon as possible and the transponder should be operated as directed by ATC.

8.7 COMMUNICATION FAILURE

In the event of a communication failure, the pilot should adjust the transponder to reply on Code 7600 to alert air traffic control (ATC) of the situation. This does not relieve the pilot of the requirement to comply with the appropriate communications failure procedures for instrument flight rules (IFR) flight.

8.8 UNLAWFUL INTERFERENCE

Canada, along with other nations, has adopted a special secondary surveillance radar (SSR) transponder code (7500) for use by pilots of aircraft subjected to an act of unlawful interference. Air traffic control (ATC) does not assign this code (7500) unless the pilot informs ATC of an act of unlawful interference in progress.

Selection of the code activates an alarm system and points out the aircraft on situation displays. If the controller doubts that an aircraft is the subject of an act of unlawful interference (as could occur when a code change was requested and the act of unlawful interference code appeared rather than the assigned code), the controller will say, “CONFIRM SQUAWK SEVEN FIVE ZERO ZERO”. If the pilot answers yes, the controller will alert the ATC system. If the pilot replies no, the controller will re-assign the proper code. If the pilot does not reply, the controller will take this as confirmation that the use of Code 7500 is intentional. If, after using Code 7500, an aircraft changes to Code 7700 or transmits a message including the phrase “TRANSPONDER SEVEN SEVEN ZERO ZERO”, this indicates that the aircraft is threatened by grave and imminent danger and requires immediate assistance.

9.0 TRAFFIC ALERT AND COLLISION AVOIDANCE SYSTEM (TCAS) AND AIRBORNE COLLISION AVOIDANCE SYSTEM (ACAS)

9.1 GENERAL

The International Civil Aviation Organization (ICAO) uses the term airborne collision avoidance system (ACAS). The term traffic alert and collision avoidance system (TCAS) refers to the system developed in the United States by the Federal Aviation Administration (FAA). These terms are generally interchangeable. Care needs to be taken when comparing ICAO definitions of ACAS II with the North American definition of TCAS II.

Specifically, the ICAO definition of a fully compliant ACAS II (see ICAO Annex 10, Volume 4, Chapter 4) is equivalent to TCAS II software version 7.1. Additional guidance and information on ACAS may be found in Transport Canada (TC) Advisory Circular (AC) 700-004.

NOTE:

For the purposes of the *Transport Canada Aeronautical Information Manual* (TC AIM), the term TCAS will be used and, where necessary, a specific software version will be identified for clarity.

TCAS equipment alerts flight crews when the path of the aircraft is predicted to potentially collide with that of another aircraft. A TCAS-equipped aircraft interrogates other aircraft in order to determine their position. TCAS is designed to operate independently of air traffic control (ATC) and, depending on the type of TCAS, will display proximate traffic and provide traffic advisories (TAs) and resolution advisories (RAs).

TAs provide information on proximate traffic and indicate the relative positions of intruding aircraft. TAs are intended to assist flight crew in visual acquisition of conflicting traffic and to prepare pilots for the possibility of an RA.

RAs are divided into two categories: preventative advisories, which instruct the pilot to maintain or avoid certain vertical speeds; and corrective advisories, which instruct the pilot to deviate from the current flight path (e.g. “CLIMB” when the aircraft is in level flight).

There are two types of TCAS:

- (a) TCAS I is a system, which includes a computer and pilot display(s), that provides a warning of proximate traffic (TA) to assist the pilot in the visual acquisition of intruder aircraft and in the avoidance of potential collisions (it does not provide RAs).
- (b) TCAS II is a system, which includes a computer, pilot display(s), and a Mode S transponder, that provides both TAs and vertical plane RAs. RAs include recommended escape manoeuvres, only in the vertical dimension, to either increase or maintain existing vertical separation between aircraft.

NOTE:

There is currently no TCAS equipment capable of providing RAs in the lateral direction.

The following paragraphs and table describe the TCAS levels of protection versus aircraft equipage.

Intruder aircraft without transponders are invisible to TCAS-equipped aircraft and thus TAs or RAs are not provided.

Intruder aircraft equipped with only a Mode A transponder are not tracked or detected by TCAS II, because TCAS II does not use Mode A interrogations. Mode A transponder aircraft are invisible to TCAS-equipped aircraft.

Intruder aircraft equipped with a Mode C transponder without altitude input will be tracked as a non-altitude replying target. Neither a data tag nor a trend arrow will be shown with the

traffic symbol. These aircraft are deemed to be at the same altitude as own aircraft.

In an encounter between two TCAS II-equipped aircraft, their computers will communicate using the Mode S transponder data link, which has the capability to provide complementary RAs (e.g. one climbing and one descending).

Table 9.1—TCAS Levels of Protection

| | | Own Aircraft Equipment | |
|-----------------------------|---|-------------------------------|--------------------------------|
| | | TCAS I | TCAS II |
| Intruder Aircraft Equipment | Non-transponder-equipped or Mode A transponder only | Not tracked and not displayed | Not tracked and not displayed |
| | Mode C or Mode S transponder | TA | TA and vertical RA |
| | TCAS I | TA | TA and vertical RA |
| | TCAS II | TA | TA and coordinated vertical RA |

9.2 TRANSPORT CANADA (TC) REGULATIONS ON TRAFFIC ALERT AND COLLISION AVOIDANCE SYSTEM (TCAS)/AIRBORNE COLLISION AVOIDANCE SYSTEM (ACAS)

The Technical Standard Order (TSO) for TCAS I is TSO-C118 or CAN-TSO-C118.

The TSO for TCAS II/ACAS II is TSO-C119 or CAN-TSO-C119. The original release of TSO-C119 was associated with software version 6.0. Since then, the following updates to TSO-C119 have been released:

- (a) *TSO-C119a (associated with software version 6.04a)*—Version 6.04a was released to address nuisance alerts which were occurring at low altitudes and during low-level manoeuvres, and to address a problem with the altitude crossing logic.

NOTE:

This version is the minimum requirement for operations in Canada when outside of reduced vertical separation minimum (RVSM) airspace.

- (b) *TSO-C119b (associated with software version 7.0)*—Version 7.0 was released to address numerous enhancements to collision avoidance algorithms, aural annunciation, and resolution advisory (RA) displays as well as changes to reduce repetitive nuisance traffic advisories (TAs) on RVSM routes in slow closure situations.

NOTE:

Software version 7.0 is the minimum required for all CARs 702, 703, 704 and 705 aeroplanes when operating inside of RVSM airspace.

- (c) *TSO-C119c (associated with software version 7.1)*—Version 7.1 was released to address reversal logic issues and flight crew misinterpretation of “ADJUST VERTICAL SPEED, ADJUST” aural annunciation. In International Civil Aviation Organization (ICAO) terminology, this is also referred to as ACAS II.

NOTES:

1. In Amendment 85 to ICAO Annex 10, Volume IV, Chapter 4, published in October 2010, ICAO has mandated that all new ACAS installations after January 1, 2014 be compliant with version 7.1 and that all ACAS units shall be compliant with version 7.1 after January 2017. Transport Canada (TC) has not initiated any rulemaking based on these ICAO requirements.
2. Be advised that if you operate in ICAO member countries after the abovementioned dates you will have to be equipped with software version 7.1.

Within some member states of the European Union and within European Civil Aviation Conference (ECAC) airspace, equipage with TCAS II software version 7.1 will be required earlier than the ICAO mandated dates.

The TSO for Mode S transponders is TSO-C112 or CAN-TSO-C112. The following table and associated notes summarize the TCAS/ACAS requirements for CAR Part VII air operators.



Table 9.2—TCAS/ACAS Requirements for CAR Part VII Air Operators

| CAR | TCAS I* | TCAS II** |
|--------|---|---|
| 702.46 | Not required | Required for turbine-powered aeroplanes of MCTOW exceeding 15 000 kg (33 069 lb). (See notes 1 and 2 below.) |
| 703.70 | Minimum required for aeroplanes of MCTOW exceeding 5 700 kg (12 566 lb) outside of RVSM airspace. (See note 1 below.) | Not required but acceptable outside of RVSM airspace. Required when operating in RVSM airspace. (See note 1 below.) |
| 704.70 | Minimum required for aeroplanes of MCTOW exceeding 5 700 kg (12 566 lb) outside of RVSM airspace. (See note 1 below.) | Required for turbine-powered aeroplanes of MCTOW exceeding 15 000 kg (33 069 lb). (See note 1 below.) |
| 705.83 | Minimum required for non-turbine-powered aeroplanes outside of RVSM airspace. (See note 1 below.) | Required for turbine-powered aeroplanes. (See note 1 below.) |

* Equivalent to CAN-TSO-C118

** CAN-TSO-C119a (version 6.04a) outside of RVSM airspace or CAN-TSO-C119b (version 7.0) inside of RVSM airspace and Mode S transponder CAN-TSO-C112

NOTES:

1. TCAS II (CAN-TSO-C119b [software version 7.0] or more recent) and Mode S transponder (CAN-TSO-C112 or more recent) are required for operations in RVSM airspace.
2. Not required when engaged in or configured for firefighting, aerial spray services, or aerial survey and operated only in low-level airspace.

It is strongly recommended that foreign operators comply with TCAS equipage requirements as outlined above when operating within Canadian airspace.

There are currently no *Canadian Aviation Regulations* (CARs) requiring private operators (CAR 604) to be equipped with TCAS. However, private operators are advised that ICAO Annex 6, Part II, 3.6.9.2 requires that: “All turbine-engined aeroplanes of a maximum certificated take-off mass in excess of 15 000 kg, or authorized to carry more than 30 passengers, for which the individual airworthiness certificate is first issued after 1 January 2007, shall be equipped with an airborne collision avoidance system (ACAS II).” This means that affected private operators flying into ICAO member countries must be equipped with ACAS II.

9.3 USE OF THE TRAFFIC ALERT AND COLLISION AVOIDANCE SYSTEM (TCAS) OUTSIDE OF CANADA

Numerous countries have operational regulations which require certain aircraft to be equipped with a traffic alert and collision avoidance system (TCAS). If you are planning on operating your aircraft in a foreign country, consult that country’s regulations to determine TCAS equipage requirements.

Canadian air operators must meet the following TCAS requirements to operate in U.S. airspace (see Federal Aviation Administration [FAA] Federal Aviation Regulations [FAR] 129.18):

- (a) TCAS I: Turbine-powered aeroplane with a passenger-seat configuration, excluding any pilot seat, of 10–30 seats.
- (b) TCAS II: Turbine-powered aeroplane of more than 33 000 lb maximum certificated takeoff weight (MCTOW).

Canadian air operators planning operations in U.S. airspace are also advised to review FAA Advisory Circular (AC) 120-55C—*Air Carrier Operational Approval and Use of TCAS II* (as amended).

For Canadian air operators planning operations in Europe, details of European requirements are available at <<https://www.eurocontrol.int/system/acas>>.

9.4 OPERATIONAL APPROVAL

For Canadian air operators, traffic alert and collision avoidance system (TCAS) operational approval is accomplished through Transport Canada (TC) approval of: pertinent training; checking and currency programs; checklists; standard operating procedure (SOP) operations or training manuals; maintenance programs; minimum equipment lists (MELs); or other pertinent documents.

When planning to equip with TCAS, Canadian air operators should consult their TC principle operations inspector early in their program to permit a timely response. Canadian air operators may address training, checking and currency individually or as part of an integrated program. For example, TCAS/ACAS qualification may be based on a specific aircraft (e.g. during A320 transition); may be addressed in conjunction with general flight crew qualification (e.g. during initial new hire indoctrination); or may be completed as dedicated TCAS/ACAS training and checking (e.g. completion of a standardized TCAS/ACAS curriculum in conjunction with a recurrent instrument flight test [IFT]/pilot proficiency check [PPC]).

Federal Aviation Administration (FAA) Advisory Circular (AC) 120-55C—*Air Carrier Operational Approval and Use of TCAS II* (as amended) provides information with respect to training, checking and currency in the use of TCAS. The material therein can be used by operators to assist in defining their implementation of TCAS.

EUROCONTROL has produced and published TCAS training material and information that are available at <https://www.eurocontrol.int/system/acas>.

9.5 AIRCRAFT CERTIFICATION APPROVAL

An acceptable means of demonstrating compliance with the appropriate requirements in the *Airworthiness Manual*, Chapter 525 and of obtaining airworthiness approval is to follow the method specified in the Federal Aviation Administration's (FAA) Advisory Circular (AC) 20-131A—*Airworthiness Approval of Traffic Alert and Collision Avoidance Systems (TCAS II) and Mode S Transponders* (as amended) for installation of Technical Standard Order TSO-C119a TCAS/ACAS. FAA AC 20-151B—*Airworthiness Approval of Traffic Alert and Collision Avoidance Systems (TCAS II), Versions 7.0 & 7.1 and Associated Mode S Transponders* should be followed for installations using TSO-C119b or TSO-C119c equipment.

9.6 OPERATIONAL CONSIDERATIONS

Where required by regulations to be equipped with traffic alert and collision avoidance system (TCAS), flight crews must operate with their TCAS equipment on at all times, in so far as is consistent with the aircraft flight manual (AFM) and standard operating procedures (SOPs). This is true even when operating away from major, high traffic density airports. Although TCAS will never be a complete substitute for a good lookout, good situational awareness and proper radio procedures, it has proven to be a valuable tool that provides information on potential collision hazards. Hence, flight crews should not deprive themselves of this important asset, especially in areas of mixed instrument flight rules (IFR) and visual flight rules (VFR) traffic.

For a TCAS-equipped aircraft to provide a flight crew with collision avoidance information, the TCAS unit and the transponder must be turned on and the transponder cannot be selected to STANDBY mode (i.e. powered but not transmitting data). If the transponder is not turned on and responding to interrogations, the aircraft's TCAS cannot display information about potentially conflicting aircraft nearby nor can it provide instructions to the crew to resolve impending collision threats. Failure of the TCAS computer unit itself can also occur; however, such a failure only affects the TCAS-equipped aircraft's ability to detect nearby aircraft. The aircraft containing the inoperative TCAS unit remains visible to other aircraft as long as its transponder remains operative. The consequences of a TCAS unit failure are magnified when the transponder is inoperative because not only is TCAS information lost to the affected aircraft, but the aircraft will not be visible to other airborne collision avoidance systems. Regardless of whether the transponder has failed or the TCAS has become inoperative, a flight crew's ability to mitigate the risk of collision is significantly degraded if the collision avoidance system becomes inoperative and the failure is not quickly and reliably brought to the crew's attention. Air operators are encouraged to inform pilots who use transponders or transponder/TCAS units that there may not be a conspicuous warning to indicate loss of collision protection resulting from a compromised transponder/TCAS unit. Air operators should require all pilots who use transponders or transponder/TCAS units to be familiar with the current annunciations used to

indicate that these components have failed or are compromised.

Flight crews are reminded to follow the resolution advisories (RAs) promptly and accurately, even though the RAs may change in strength and/or reverse. RA commands do not require large load factors when being followed. Any delay in responding to an RA could swiftly erode the ability to maintain or achieve adequate separation without resorting to strengthening RAs. For TCAS to provide safe vertical separation, initial vertical speed response is required within five seconds of the RA. Deviation from commands or second-guessing the commands should not occur. An RA prevails over any air traffic control (ATC) instruction or clearance.

Flight crews may have to inhibit the RA function under certain circumstances per the AFM (e.g. during an engine failure).

The TCAS system may inhibit RAs during certain flight phases, such as at low altitudes. Flight crews need to be aware of when TCAS will not provide a full range of RA commands.

Flight crews should not attempt to manoeuvre solely on the basis of traffic advisory (TA) information. The TA should trigger a visual search for traffic and a request to ATC for help in determining whether a flight path change is required. In the case of a TCAS II TA, the flight crew should prepare for a possible RA, following the TA.

TAs and RAs should be treated as genuine unless the intruder has been positively identified and assessed as constituting neither a threat nor a hazard.

Flight crews should be aware that, in accordance with the *Canadian Transportation Accident Investigation and Safety Board Act*, an incident where a risk of collision or a loss of separation occurs is considered a reportable aviation incident. Responding to an RA is considered a reportable aviation incident. For more information on this topic, visit the following links:

- (a) AC 700-004: [Airborne Collision Avoidance System Advisory Material](#); and
- (b) www.tc.gc.ca/en/services/aviation/operating-airports-aerodromes/report-incident-airport-safety.html

If a TCAS RA manoeuvre is contrary to other critical cockpit warnings, then those other warnings are respected per TCAS certification and training (i.e. responses to stall warning, wind shear and terrain awareness and warning systems [TAWs] take precedence over a TCAS RA, especially when the aircraft is less than 2 500 ft above ground level [AGL]).

Due to interference limiting algorithms, airborne collision avoidance system (ACAS) II may not display all proximate transponder-equipped aircraft in areas of high density traffic. Flight crews should not become complacent in their efforts to search the sky for other aircraft.

9.7 PILOT ACTION WHEN DEVIATING FROM CLEARANCES—REGULATIONS AND INFORMATION

Safety studies have confirmed that the significant safety benefit afforded by a traffic alert and collision avoidance system (TCAS) could be seriously degraded by a deficient response to resolution

advisories (RAs). It has also been shown that the safety benefit of TCAS is eroded when pilots do not follow the flight path guidance provided during an RA.

In view of this safety hazard and to optimize the safety benefits of TCAS, the following regulatory provisions have been established:

CAR 602.31(3) states that:

“The pilot-in-command of an aircraft may deviate from an air traffic control clearance or an air traffic control instruction to the extent necessary to carry out a collision avoidance manoeuvre, if the manoeuvre is carried out

- (a) in accordance with a resolution advisory generated by an ACAS; or
- (b) in response to an alert from a TAWS or a Ground Proximity Warning System (GPWS).”

CAR 602.31(4) states that:

“The pilot-in-command of an aircraft shall

- (a) as soon as possible after initiating the collision avoidance manoeuvre referred to in subsection (3), inform the appropriate air traffic control unit of the deviation; and
- (b) immediately after completing the collision avoidance manoeuvre referred to in subsection (3), comply with the last air traffic control clearance received and accepted by, or the last air traffic control instruction received and acknowledged by, the pilot-in-command.”

NOTE:

By following the RA guidance precisely, the magnitude of the altitude deviation can be minimized. Pilots must ensure that the manoeuvre necessary to comply with the RA (climb or descent) is not maintained after the RA is terminated.

There is information available which highlights the importance of following RAs. EUROCONTROL has issued numerous airborne collision avoidance system (ACAS) II bulletins (see <<https://www.eurocontrol.int/system/acas>>). ACAS II Bulletin Issue 1— Follow the RA, dated July 2002, describes several RA events and the consequences of the flight crew actions taken. The bulletin is informative and describes the advantages of TCAS/ACAS for collision avoidance when followed correctly. The bulletin also describes the limitations associated with the visual acquisition of traffic and those of air traffic control (ATC) situation displays.

Transport Canada (TC) recommends that operators disseminate this information to pilots for awareness and, where appropriate, establish suitable pilot training programs to ensure that flight crews follow RAs promptly and accurately, even when presented with conflicting avoidance instructions from ATC.

9.8 MODE S TRANSPONDER APPROVAL AND UNIQUE CODES

Along with performing all the functions of Mode A and C transponders, Mode S transponders also have a data link capability. Mode S transponders are an integral component of all TCAS II/ACAS II installations.

For aircraft that are not required to be equipped with TCAS/ACAS, there is no requirement to replace existing Mode A or C transponders with Mode S transponders until it becomes impossible to maintain presently installed Mode A or C transponders.

Airworthiness approval must be obtained by Canadian aircraft operators who install Mode S transponders. Federal Aviation Administration (FAA) Advisory Circular (AC) 20-131A— *Airworthiness Approval of Traffic Alert and Collision Avoidance Systems (TCAS II) and Mode S Transponders* (as amended) should be used for guidance to obtain airworthiness approval. Canadian operators should contact their regional Transport Canada (TC) office for approval details.

At the time of registration, each Canadian aircraft with a Mode S transponder will receive a unique 24-bit Mode S code assignment, which must be uploaded to the transponder, usually by the installer.

9.9 PILOT/CONTROLLER ACTIONS

In order to use a traffic alert and collision avoidance system (TCAS) in the most effective and safest manner, the following pilot and controller actions are necessary:

- (a) Pilots should not manoeuvre their aircraft in response to traffic advisories (TAs) only.
- (b) In the event of a resolution advisory (RA) to alter the flight path, the alteration of the flight path should be limited to the minimum extent necessary to comply with the RA. Aggressive manoeuvring should not be required since TCAS RAs are predicted on ¼ G manoeuvre load factors.
- (c) Pilots should notify, as soon as possible, the appropriate air traffic control (ATC) unit of the deviation and of when the deviation has ended.
- (d) When a pilot reports a manoeuvre induced by an RA, the controller should not attempt to modify the aircraft flight path until the pilot reports returning to the terms of the existing ATC instruction or clearance. Instead, the controller should provide traffic information as appropriate.
- (e) Pilots who deviate from an ATC instruction or clearance in response to an RA shall promptly return to the terms of that instruction or clearance when the conflict is resolved and advise ATC.

9.10 PILOT AND CONTROLLER PHRASEOLOGY

The current International Civil Aviation Organization (ICAO) traffic alert and collision avoidance system (TCAS) pilot/controller phraseology is detailed below (see also ICAO Doc 4444, 12.3.1.2). It should be noted that, for the purpose of phonetic clarity, the term TCAS is used.

Table 9.3—TCAS Pilot-Controller Phraseology

| Circumstances | Pilot | Controller |
|---|---|------------------------------------|
| After a flight starts to deviate from the ATC clearance or instructions to comply with a TCAS RA. | TCAS RA | ROGER |
| After the response to a TCAS RA is completed and a return to the ATC clearance or instruction is initiated. | CLEAR OF CONFLICT. RETURNING TO (assigned clearance). | ROGER (or alternative instruction) |
| After the response to a TCAS RA is completed and the assigned ATC clearance or instruction has been resumed. | CLEAR OF CONFLICT. (assigned clearance) RESUMED. | ROGER (or alternative instruction) |
| After an ATC clearance or instruction contradictory to the TCAS RA is received, the flight crew will follow the RA and inform ATC directly. | UNABLE, TCAS RA | ROGER |

10.0 SATELLITE SYSTEMS

10.1 GENERAL

Satellite systems used for aviation are defined by different orbits: low earth orbit (LEO), medium earth orbit (MEO) and geosynchronous earth orbit (GEO). A special case of GEO is the geostationary earth orbit (or geosynchronous equatorial orbit), which is a circular geosynchronous orbit at zero inclination (that is, directly above the equator). The altitude of the orbit determines the surface area of the Earth that can be illuminated by the satellite signal: the higher the orbit, the larger the signal footprint. Propagation losses from satellites at higher orbits are offset by the increased complexity of the antenna systems, along with higher transmitter power. A LEO satellite’s footprint is smaller, which means that a higher number of satellites are required to provide seamless coverage, but the antennas are much simpler and have a reduced radio frequency power requirement on the user end.

10.2 SATELLITE SERVICE PROVIDERS

A number of providers offer telephone and data services to the aeronautical market via satellite. Iridium offers a low earth orbit (LEO) satellite system, while Inmarsat and the Japan Meteorological Agency operate geosynchronous earth orbit (GEO) satellite systems. These satellite systems use frequencies reserved for aeronautical safety services.

Iridium offers a constellation of 66 cross-linked satellites at an altitude of 780 km. Six orbital planes, with 11 satellites in each orbital plane, provide global coverage. Additionally, there are a number of spare satellites to replace any in-orbit failures. At that altitude, each satellite covers a circular area 4 500 km in diameter, and is in view for approximately nine minutes to anyone located on the ground.

The Inmarsat network uses geostationary earth satellites at an altitude of 35 786 km. At that altitude above Earth, each satellite’s footprint covers approximately 120° of longitude at the equator and stretches to approximately 82° north and 82° south latitude. The orbital period of each satellite is exactly the same as the rotation period of the Earth, so each satellite appears to remain in the same position.

Japan’s multifunctional transport satellite (MTSAT) functionality is equivalent to that of Inmarsat, except that the MTSAT constellation, centered over Japan, only provides a coverage footprint to Asia and the Pacific Ocean.

11.0 EMERGENCY AUTOMATION SYSTEMS

11.1 AUTOMATED EMERGENCY DESCENT MANAGEMENT SYSTEMS

From small general aviation aircraft to large air transport category aircraft, several aircraft manufacturers offer automated emergency descent management systems. While depressurization events are extremely rare, these systems can activate when either the cabin pressure drops below predetermined limits or when pilot-interaction monitors get triggered, and they can automate certain functions when a rapid descent might be required. After attempting to alert the flight crew, who may be potentially non-responsive and/or hypoxic, the systems are designed to automatically engage and descend the aircraft to a safe altitude.

Once the automated emergency descent management system has determined the appropriate minimum sector altitude (MSA) or calculated an escape route for the aircraft based on underlying terrain, the autopilot and autothrottle will engage and descend the aircraft as appropriate. Depending on the configuration, some aircraft automatically initiate a parallel offset when starting the descent while others could turn to a new heading, such as 90° from the current aircraft heading. If the aircraft happens to be traffic alert and collision avoidance system (TCAS)/airborne collision avoidance system (ACAS) equipped, and if the onboard system can determine that another aircraft is in conflict, the automated emergency descent management system may have the additional capability of carrying out resolution advisories during the emergency descent.

When beginning the descent, some automated emergency descent management systems can adjust the transponder code to 7700, select Emergency/Priority status in the automatic dependent surveillance-broadcast (ADS-B) subfield, and may even be capable of broadcasting messages to air traffic control (ATC) using a digitized voice. These voice broadcasts are typically transmitted on the very high frequency (VHF) radio frequency last used by

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the pilot and/or over the emergency frequency 121.5 MHz. Highly automated systems may also be able to send controller-pilot data link communications (CPDLC) messages to ATC through datalink.

11.2 EMERGENCY AUTOMATIC LANDING SYSTEMS

Some light aircraft are equipped with an emergency automatic landing system that can perform a completely autonomous landing in an emergency situation. These systems could be triggered by automated emergency descent management systems, envelope protection systems, or they can even be engaged manually by a passenger if the pilot has become incapacitated. Upon activation, emergency automatic landing systems will determine the optimal route to a suitable aerodrome, fly the aircraft to a selected runway, and perform a survivable landing. Regardless if the aircraft was being operated under visual flight rules (VFR) or instrument flight rules (IFR), once a destination runway has been determined, the onboard system generates a path to the final approach fix which avoids terrain, obstacles and, depending on aircraft options, even severe weather along the way.

Emergency automatic landing systems select the most suitable runway based on several factors, although these systems normally prefer airports with control towers since they offer better coordination with other traffic as well as emergency services on the ground. It should be noted that these systems can select suitable runways without consideration of international boundaries.

Emergency automatic landing systems will normally maintain straight and level flight for a brief period, allowing air traffic control (ATC) to identify the activation and begin clearing nearby traffic out of the way. In the event the aircraft is surrounded by terrain upon activation, these systems may initiate a straight-line climb or a climb in a present-position holding pattern and then continue on to the selected runway once the aircraft is clear of the terrain.

After an emergency automatic landing system has been activated, the transponder code will automatically be changed to 7700 and the Emergency/Priority status in the automatic dependent surveillance-broadcast (ADS-B) subfield will be selected. Using a digitized voice, the system may broadcast messages such as the following over the emergency frequency 121.5 MHz, over the selected aerodrome tower/mandatory frequency (MF)/universal communications (UNICOM) frequency, and sometimes over the very high frequency (VHF) radio frequency last used by the pilot:

*MAYDAY, MAYDAY, MAYDAY, AIRCRAFT
<REGISTRATION> HAS ACTIVATED AN EMERGENCY
AUTOMATIC LANDING SYSTEM. STAND BY FOR
INFORMATION.*

*AIRCRAFT <REGISTRATION>, PILOT
INCAPACITATION, <DISTANCE FROM DESTINATION
AIRPORT> MILES <DIRECTION FROM DESTINATION
AIRPORT> OF <DESTINATION AIRPORT>,
EMERGENCY AUTOLAND IN <ESTIMATED TIME
REMAINING> ON <RUNWAY> AT <DESTINATION
AIRPORT>.*

NOTE:

Not all remote communication facilities (peripheral station [PAL], remote aerodrome advisory service [RAAS], remote communications outlet [RCO] and flight information service en route [FISE] RCO) have 121.5 MHz capability. When an aircraft has activated an emergency automatic landing system, other aircraft operating in the vicinity who are able to hear transmissions on 121.5 MHz should attempt to relay any emergency messages to an air traffic service (ATS) facility.

The autopilot and autothrottle fly the aircraft to the runway and can initiate a holding pattern if necessary at the final approach fix to slow the aircraft and prepare for landing, while the emergency automatic landing systems lower the flaps and landing gear at the appropriate time, perform the flare and touchdown, and apply the wheel brakes. Once the aircraft has come to a halt on the runway, the aircraft should be met by emergency services.

NOTE:

Some emergency automatic landing systems may not automatically shut down the engines of the aircraft.

After landing, these systems may continue broadcasting messages such as the following until they are deactivated:

*ATTENTION, <DESTINATION AIRPORT> TRAFFIC,
AIRCRAFT <REGISTRATION> DISABLED ON
RUNWAY <RUNWAY>.*

The avionics in the aircraft will normally display appropriate instructions for airport responders to disengage the brakes and deactivate the emergency automatic landing system so that the aircraft can be removed from the runway.