Transport Canada Transports Canada

TP 15263E
(08/2014)

Knowledge Requirements

for

Pilots of Unmanned Air Vehicle Systems

UAV 25 kg or less,
Operating within Visual Line of Sight

First Edition
August 2014

RDIMS 8830972

Canada

This document was submitted to Transport Canada by a joint industry-government working group.

Additional knowledge material is also available in a document entitled “Annex to Knowledge Areas – UAV MTOW 25kg or less operated within VLOS”. That additional material addresses terms and conditions of an SFOC that a pilot would be expected to have been taught in a ground school.

TABLE OF CONTENTS

GENERAL INFORMATION.....iv
PILOT KNOWLEDGE REQUIREMENTS.....iv
EXAMINATION.....iv
AIR LAW..... 1
SECTION 1: AIR LAW AND PROCEDURES..... 1
NAVIGATION.....10
SECTION 2: NAVIGATION AND NAVIGATION AIDS.....10
METEOROLOGY.....14
SECTION 3: METEOROLOGY.....14
AERONAUTICS - GENERAL KNOWLEDGE.....19
SECTION 4: AIRFRAMES, ENGINES AND SYSTEMS.....19
SECTION 5: THEORY OF FLIGHT.....22
SECTION 6: FLIGHT INSTRUMENTS.....26
SECTION 7: FLIGHT OPERATIONS.....28
SECTION 8: HUMAN FACTORS.....33
RADIOTELEPHONY.....35
ENQUIRIES.....36
RECOMMENDED STUDY MATERIAL.....36

GENERAL INFORMATION

The Canadian Aviation Regulatory Advisory Council (CARAC) Unmanned Air Vehicle (UAV) System Program Design Working Group has made recommendations for amendments to existing regulations and standards, and introduced new regulations and standards for the safe integration of small UAV operations within visual line-of-sight (VLOS) under visual flight rules (VFR) in Canadian airspace.

The key principles for UAV related regulatory changes were approved by the CARAC Technical Committee in June 2012 and then by the Transport Canada Canadian Aviation Regulatory Committee (CARC) in October 2012. They are now being adopted as Best Practice[1] guidance for Transport Canada Inspectors and applicants for a Special Flight Operations Certificate (SFOC) - Unmanned Air Vehicle Systems.

These Best Practices are comprised of three areas: pilot, UAV system design standard, and operator requirements. SFOC applicants demonstrating compliance with all three areas may be eligible for SFOCs of greater scope and/or duration; they may also benefit from more-timely approval of SFOC applications.

This document is provided for the guidance of organizations or individuals intending to provide ground school instruction to pilots seeking compliance with the Best Practices for pilots of small UAV systems. These training organizations will be expected to provide Transport Canada with a written declaration attesting to the compliance of their courseware and testing. Thereafter, SFOC applicants with pilots who have successfully completed such a compliant course will be able to reference that course and ground school provider in their SFOC application as proof of pilot knowledge.

Regulations and Standards for the issue of a Pilot Permit – Small UAV Systems – Restricted to Visual Line of Sight (VLOS) will be specified in future Canadian Aviation Regulations (CARs). Until that time, complying with the proposed regulations will indicate that the pilot meets the recommended Best Practices expected in the approval process for an SFOC.

PILOT KNOWLEDGE REQUIREMENTS

This document provides topics and sample objectives in the cognitive domain. The sample objectives provided are not a complete list of objectives - their purpose is to illustrate the depth of knowledge expected in the subject areas.

Future applicants for a Pilot Permit – Small UAV Systems – Restricted to VLOS will be required to complete a course of training and will be required to prove their knowledge by writing an examination on the subjects contained in this guide. Applicants must be able to read the examination questions in either English or French without assistance.

EXAMINATION

Applicants shall have obtained a minimum of 60% on a written examination of these subjects.

[1] Best practices documentation is currently available from http://www.unmannedsystems.ca

At this time of writing, it is expected that the organizations conducting the ground school will create and administer an appropriate examination.

The examination subjects, in general terms, are

Mandatory Subjects	Related Subjects in this Guide	Page
AIR LAW	Air Law and Procedures – Section 1	1
NAVIGATION	Navigation and Radio Aids – Section 2	10
METEOROLOGY	Meteorology – Section 3	14
AERONAUTICS - GENERAL KNOWLEDGE	Airframes, Engines, and Systems–Section 4	19
	Theory of Flight – Section 5	22
	Flight Instruments – Section 6	26
	Flight Operations – Section 7	28
	Human Factors – Section 8	33
RADIOTELEPHONY……..	Aeronautical and Crew – Section 9	35

CURRENT REGULATIONS AND SFOC CONDITIONS

By necessity, this document makes reference to current regulations, as well as operating conditions that are commonly found as terms or restrictions in an SFOC-UAV System. Note the following in this document:

- The existing Canadian Air Regulations (CARs) are referenced by their section numbers.

- SFOC conditions that may modify or augment CARs are indicated by an asterisk (*) preceding the section number. Details on these operating conditions can be obtained from Unmanned Systems Canada (USC), who are part of the Working Groups and Technical Committees. Their web address is http://www.unmannedsystems.ca/

AIR LAW

SECTION 1: AIR LAW AND PROCEDURES

Knowledge Area	**Sample Learning Objectives** The pilot operating small UAVs within visual line of sight must be able to:
CARs Some Canadian Aviation Regulations (CARs) refer to their associated standards. Questions from the CARs may test knowledge from the regulation or the standard. **PART I – GENERAL PROVISIONS** 101 – INTERPRETATION 101.01 Interpretation (Definitions) 103 – ADMINISTRATION AND COMPLIANCE COMPLIANCE 103.02 Inspection of Aircraft, Requests for Production of Documents and Prohibitions 103.03 Return of Canadian Aviation Documents 103.04 Record Keeping	• State who may demand to inspect aviation documents. • State the definition of “operator” with respect to aircraft operations and the holder of a SFOC. • Define common terms used in UAV system operations such as: command and control link, pilot, operator, handover, lost link.
PART III – AERODROMES AND AIRPORTS 300 – INTERPRETATION 300.01 Interpretation 301 – AERODROMES	• Explain that persons, vehicles, obstacles and operations at aerodromes are subject to the approval of the aerodrome operator and the appropriate air traffic control unit.

301.01 Application 301.08 Prohibitions 301.09 Fire Prevention 302 – AIRPORTS 302.10 Prohibitions 302.11 Fire Prevention	
PART IV - PERSONNEL LICENSING AND TRAINING (*) 421.** Requirements for UAV Pilots – Small UAVs Restricted to VLOS – Age (18) – Medical fitness (Cat 4, valid for 60 months) – Knowledge (this document) – Experience	• State the minimum age and recommended best practices for medical fitness of UAV pilots.
PART VI – GENERAL OPERATING AND FLIGHT RULES 600 – INTERPRETATION 600.01 Interpretation 601 – AIRSPACE AIRSPACE STRUCTURE, CLASSIFICATION AND USE 601.01 Airspace Structure 601.02 Airspace Classification 601.03 Transponder Airspace 601.04 IFR or VFR Flight in Class F Special Use Restricted Airspace or Class F Special Use Advisory Airspace (*) 601.08 VFR Flight in Class C Airspace	• Describe the horizontal and vertical limits of the various classifications of airspace, control areas, special use airspace. • Describe the communications required with Air Traffic control (ATC) for operating a small UAV within VLOS in class C or D airspace. • Describe the circumstances when a small UAV is permitted to be operated in the vicinity of a forest fire. • Describe the process required to legally use a LIDAR (Light Detection and Ranging) on a small UAV.

(*) 601.09 VFR Flight in Class D Airspace AIRCRAFT OPERATING RESTRICTIONS AND HAZARDS TO AVIATION SAFETY 601.14 Interpretation 601.15 Forest Fire Aircraft Operating Restrictions 601.16 Issuance of NOTAM for Forest Fire 601.17 Exceptions 601.20 Projection of Directed Bright Light Source at an Aircraft 601.21 Requirement for Notification 601.22 Requirement for Pilot-in-command	

602 – OPERATING AND FLIGHT RULES GENERAL 602.01 Reckless or Negligent Operation of Aircraft 602.02 Fitness of Flight Crew Members 602.03 Alcohol or Drugs – Crew Members (*) 602.05 Compliance with Instructions 602.07 Aircraft Operating Limitations (*) 602.08 Portable Electronic Devices 602.10 Starting and Ground Running of Aircraft Engines 602.11 Aircraft Icing 602.12 Overflight of Built-up Areas or Open-air Assemblies of Persons during Take-offs, Approaches and Landings (as revised) (*) 602.13 Take-offs, Approaches and Landing within Built-up Areas of Cities and Towns (as revised) 602.14 Minimum Altitudes and Distances 602.15 Permissible Low Altitude Flight (*) 602.19 Right-of-Way – General 602.20 Right-of-Way – Aircraft Manoeuvring on Water	• Recall the prohibitions against reckless operations. • Explain that pilots have a duty to prevent hazards or injury to others. • Recall that all crew members must comply with the instructions of the pilot in command. • State that UAVs may not be left unattended if the engine or motor could start. • State the minimum distances from people not involved in the UAV operation. • Explain which aircraft has the right of way with respect to small UAVs and other aircraft. • Describe the requirements for communications between the pilot-in-command and visual observers. • List the operational and emergency equipment that must be available to UAV crew members (checklists, operating manual, fire extinguishers, etc). • State that pilots of small UAVs shall avoid flying the UAV in the traffic pattern at an aerodrome. • Recall the minimum conditions for VFR flight in uncontrolled airspace.

602.21 Avoidance of Collision 602.22 Towing 602.23 Dropping of Objects 602.24 Formation Flight 602.27 Aerobatic Manoeuvres – Prohibited Areas and Flight 602.30 Fuel Dumping 602.31 Compliance with Air Traffic Control Instructions and Clearances 602.32 Airspeed Limitations (*) 602.40 Landing at or Take-off from an Aerodrome at Night 602.41 Unmanned Air Vehicles (*) 602.** UAV Visual Observers (*) 602.** UAV Lost Link OPERATIONAL AND EMERGENCY EQUIPMENT REQUIREMENTS 602.58 Prohibition 602.59 Equipment Standards (*) 602.** Requirements for Small UAVs FLIGHT PREPARATION, FLIGHT PLANS & FLIGHT ITINERARIES 602.70 Interpretation – Definitions 602.71 Pre-flight Information 602.72 Weather Information PRE-FLIGHT AND FUEL REQUIREMENTS 602.86 Carry-on Baggage, Equipment and Cargo 602.87 Crew Member Instructions	• Describe the actions to be taken in the event of a two-way radiocommunications failure when flying in class C and D airspace.

OPERATION AT OR IN THE VICINITY OF AN AERODROME (*) 602.96 General 602.97 VFR and IFR Aircraft Operations at Uncontrolled Aerodromes within a Mandatory Frequency (MF) Area 602.98 General MF Reporting Requirements 602.99 MF Reporting Procedures before Entering Manoeuvring Area 602.100 MF Reporting Procedures on Departure 602.101 MF Reporting Procedures on Arrival 602.102 MF Reporting Procedures when Flying Continuous Circuits 602.103 Reporting Procedures when Flying Through an MF Area VISUAL FLIGHT RULES 602.114 Minimum Visual Meteorological Conditions for VFR Flight in Controlled Airspace 602.115 Minimum Visual Meteorological Conditions for VFR Flight in Uncontrolled Airspace 602.117 Special VFR Flight RADIOCOMMUNICATIONS 602.136 Continuous Listening Watch 602.138 Two-way Radiocommunication Failure in VFR Flight	
603 – SPECIAL FLIGHT OPERATIONS MISCELLANEOUS SPECIAL FLIGHT OPERATIONS 603.65 Application 603.66 Certification Requirements	• Recall the requirements for an SFOC when operating a UAV. • Interpret the contents of Operator Certificate (Air Operator Certificate, Flight Training Unit Operator Certificate, Private Operator Certificate, Special Flight Operations Certificate)

603.67 Issuance of a Special Flight Operations Certificate 603.68 Contents of a SFOC	• State that the declarations made in the application are binding under the SFOC.
605 – AIRCRAFT REQUIREMENTS GENERAL 605.04 Availability of Aircraft Flight Manual 605.06 Aircraft Equipment Standards and Serviceability 605.08 Unserviceable and Removed Equipment – General (*) 605.09 Unserviceable and Removed Equipment – Aircraft with a Minimum Equipment List 605.10 Unserviceable and Removed Equipment – Aircraft without a Minimum Equipment List AIRCRAFT EQUIPMENT REQUIREMENTS (*) 605.30 De-icing or Anti-icing Equipment 605.35 Transponder and Automatic Pressure Altitude Reporting Equipment (*) 605.38 ELT (*) 605.** System Capability Requirements for UAVs (*) 605.** Radio Frequency Interference - UAV AIRCRAFT MAINTENANCE REQUIREMENTS (*) 605.85 Maintenance Release and Elementary Work (*) 605.88 Inspection After Abnormal Occurrences TECHNICAL RECORDS (*) 605.92 Requirement to Keep Technical Records 605.93 Technical Records – General	• State that a system may not be operated with unserviceable equipment that is otherwise required by the manufacturer. • State the minimum capability requirements for UAV systems. • Recall that aircraft must have a transponder in transponder airspace, unless approved by ATC. • State the requirements to keep technical records. • Explain why UAVs must never be flown with ELTs on board. • State the required content of a UAV Journey Log. • Give examples of Elementary Work that can be accomplished by the UAV crew. • Explain the lighting requirements for VLOS UAV night operations.

605.94 Journey Log Requirements (*) 605.95 Journey Log 605.97 Transfer of Records	
606 – MISCELLANEOUS 606.01 Munitions of War 606.02 Liability Insurance	

New CAR Subpart – UAV OPERATIONS new– SMALL UAV - VLOS OPERATIONS GENERAL (*) new Application FLIGHT OPERATIONS (*) new Operating Instructions (*) new Operational Control (*) new Operational Flight Plan (*) new Maintenance of Aircraft (*) new VFR Flight Minimum Flight Visibility – Uncontrolled Airspace (*) new Built-up Areas and Aerial Work Zones PERSONNEL REQUIREMENTS (*) new Designation of Pilot-in-command (*) new Flight Crew Member Qualifications TRAINING (*) new Training Program (*) new Training and Qualification Record MANUALS (*) new Distribution of Company Operations Manual (*) new Standard Operating Procedures	• Explain that an Operating Certificate (SFOC) is required for commercial operations. • Describe the recommended best practices for an Operational Flight Plan. • Identify circumstances that require an Aerial Work Zone Plan. • Explain why there is always a pilot-in-command when a UAV is in flight. • Explain that a crew member must complete the company training program before being assigned duties. • Explain that operations must be conducted in accordance with the Company Operations Manual. • Give examples of the information found in a Company Operations Manual. • Identify the documents that must be accessible to the flight crew during operations
TRANSPORTATION SAFETY BOARD OF CANADA (TSB) – (TC AIM - GEN 3.0)	• State that the purpose of accident investigation is to prevent recurrence. • State the types of accidents and incidents that must be reported to the Transportation Safety Board of Canada. • State that accident sites must not be disturbed except to

	protect lives or prevent further damage.
AIR TRAFFIC SERVICES AND PROCEDURES 1 Air Traffic and Advisory Services 2 Flight Service Stations, Flight Information Centres 3 Communication Procedures 5 ATC Clearances/Instructions/ Mandatory Readback Procedures 7 Aerodrome Operations – Controlled 8 Aerodrome Operations – Uncontrolled 9 Mandatory and Aerodrome Traffic Frequencies	• Determine who provides coordination or air traffic control service for the airspace being used (if applicable). • Determine the MF/ATF and enroute frequencies (if applicable) for the operating area. • Explain any traffic patterns of passing aircraft. • Anticipate patterns of manned aircraft sharing the airspace. • Determine the aeronautical radio frequencies in use for this airspace. • Use appropriate phraseology in radio communication. • Recognize clearances and instructions aimed at other aircraft. • Interpret the CFS with respect to airspace and location procedures.
OTHER LEGISLATION 1 Air Transportation Regulations (sections 3 and 7) 2 Canada Labour Code Part II - Occupational Safety & Health, Employee Rights & Duties (sections 126, 127 and 128)	• Explain that both the employer and employee are responsible for safe working conditions. • State that employees shall report unsafe working conditions to their supervisors, and may refuse dangerous work unless that refusal puts others at risk.

NAVIGATION

SECTION 2: NAVIGATION AND NAVIGATION AIDS

Knowledge Areas	Sample Learning Objectives The pilot operating small UAVs within visual line of sight must be able to:
DEFINITIONS 1 Meridian 2 Prime Meridian 3 Longitude 4 Equator 5 Latitude 6 Variation 7 Deviation 8 Track 9 Heading 10 Airspeed 11 Ground Speed 12 Air Position 13 Ground Position 14 Bearing 15 Wind Velocity 16 Drift	
MAPS AND CHARTS 1 VTA 2 VNC 3 Topographical Symbols 4 Elevation and Contours (Relief) 5 Aeronautical Information 6 Scale and Units of Measurement 7 Locating Position by Latitude and Longitude	• Describe the possible effects of mixing map projections and datums. • Give examples of the different projections and datums that can be used in a ground control station. • Locate your positions on an aeronautical chart. • Interpret topographical information from aeronautical charts. • Interpret aeronautical information from aeronautical charts.

8 GIS Datum, WGS84 Datum, other datums	• Determine the validity/currency of aeronautical charts.
TIME AND LONGITUDE 1 24 Hour System 2 Conversion of UTC to Local and Vice Versa 3 Sunrise and sunset	• Convert UTC to local time & vice versa. • Determine local time of sunrise/sunset.
PILOT NAVIGATION 1 Use of Aeronautical Charts 2 Measurement of Track and Distance 3 Map Reading 4 Ground Speed Checks and E.T.A. Revisions 5 Variation 6 True Track/Magnetic Track 7 True/Magnetic/ Headings 8 True Airspeed/Ground Speed (TAS, G/S)	• Explain how to use the software to determine position and plot a track. • Using simple mental calculations, estimate, crab angles while tracking in a cross wind. • Use appropriate average winds and airspeeds for navigation. • Explain the difference between track and heading. • Explain the difference between true and magnetic heading. • Describe location and activities referring to appropriate aeronautical charts and aeronautical reference points. • Identify the class of airspace and proximity of aerodromes to the operating location using aeronautical charts. • Verify that the map loaded in the control station uses the same reference as the mission plan, aircraft navigation system and tracking antenna if applicable. • Describe the possible problems if a visual observer is not correctly oriented.
TRIANGLE OF VELOCITIES 1 True Airspeed and Heading 2 Wind Velocity 3 Ground Speed and Track	• Given wind speed and air speed, estimate ground speed and distance covered.

PRE-FLIGHT PREPARATION
1 Factors Affecting Choice of Route
2 Navigation Plan
3 NOTAM
4 Fuel Requirements
5 Weight and Balance
6 Use of Canada Flight Supplement
7 Documents to be available at the GCS
8 Aircraft Serviceability, configuration
	• Describe the factors that will influence your choice of route (built-up areas, restricted airspace, property lines, etc.).
	• Obtain NOTAMS, and interpret them.
	• Identify the NOTAM issuing office and describe the contents of a NOTAM.
	• Demonstrate how to use the CFS to determine type and radius of airspace, frequencies, aerodrome operator contact information, nearest FIC/ATS unit for emergency contact, etc.
	• Determine the contact information for EMS and local authorities.
	• List the documents that must be available at the Ground Control Station.
	• Determine the serviceability of
	  o Aircraft.
	  o Control Station.
	  o RF equipment.
	  o Launch and recovery equipment.
	  o Software loads and versions.
	  o Correct databases (e.g. maps) loaded.
	  o Batteries (capacity (i.e due to age), history, charge status).
	• Demonstrate how to verify the flight plan data file is correct and complete in the autopilot.

RADIO THEORY 1 Characteristics of Low/High and Very & Ultra High Frequency Radio Waves 2 Frequency Bands Used in Navigation and Communication 3 Operational Limitations	• Explain the characteristics of radio wave propogation. • Describe the factors that affect radio reception range. • Identify sources of RF interference. • Describe how to assess an RF environment. • Explain the function of RF spectrum analyzer.

GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS/GPS) 1 Principles of Operation 2 Serviceability Checks	• Describe how GNSS systems may be enhanced by augmentation systems. • Provide an example of how DGPS might be used for landing. • Discuss the significance of GPS loss in flight. • Describe what can affect GPS performance (number of satellites, weather).
OTHER RADIO AND RADAR AIDS – BASIC PRINCIPLES AND USE 1 Transponder 2 Locator devices	• Describe the function of an ATC RADAR transponder. • Describe the function of ADS-B.

METEOROLOGY

SECTION 3: METEOROLOGY

Knowledge Areas	**Sample Learning Objectives** The pilot operating small UAVs within visual line of sight must be able to:
THE EARTH'S ATMOSPHERE 1 Composition and Physical Properties 2 Vertical Structures 3 The Standard Atmosphere 4 Density and Pressure 5 Mobility 6 Expansion and Compression	• Describe the physical composition of the atmosphere. • Explain the change in weather with expansion of air. • Define Standard Atmosphere.
ATMOSPHERIC PRESSURE 1 Pressure Measurements 2 Station Pressure 3 Sea Level Pressure 4 Pressure System and their Variations 5 Effects of Temperature 6 Isobars 7 Horizontal Pressure Differences	• Define atmospheric pressure, station pressure, sea level pressure. • Explain the atmospheric pressure variation with height. • Explain movement of air masses as resulting from high and low pressure systems, convergence, and divergence • Relate weather characteristics to pressure systems.
METEOROLOGICAL ASPECTS OF ALTIMETRY 1 Pressure Altitude 2 Density Altitude 3 Altimeter Settings	• Assess weather and density altitude for anticipated performance (take-off and launch) and flight envelope limitations. • Calculate pressure altitude and density altitude.

TEMPERATURE 1 Temperature Scale – Fahrenheit/ Celsius 2 Heating/Cooling of the Atmosphere – Convection/Advection/ Radiation 3 Horizontal Differences 4 Temperature Variations with Altitude	• Convert temperature between Celsius and Fahrenheit. • Explain the mechanisms of atmospheric heating and cooling. • Describe the effects that temperature can have when flying near a shoreline.
MOISTURE 1 Relative Humidity/Dewpoint 2 Change of State 3 Sublimation/Condensation 4 Cloud Formation 5 Precipitation 6 Saturated/Dry Adiabatic Lapse Rate	• Explain the effect of moisture and temperature on the formation of clouds, height of cloud base . • Calculate the height of cloud base given dewpoint, and temperature. • Discuss the significance of cloud base height on potential air traffic.
STABILITY AND INSTABILITY 1 Lapse Rate and Stability 2 Modification of Stability 3 Characteristics of Stable/Unstable Air 4 Surface Heating/Cooling 5 Lifting Processes 6 Subsidence/Convergence	• Characterize the effects of stable and unstable air masses (visibility, smoothness, smog layers).
CLOUDS 1 Classification 2 Formation and Structure 3 Types and Recognition 4 Associated Precipitation and Turbulence	• Identify cloud types and their impact on flying operations. • Discuss the significance of observed vertical cloud development.

SURFACE BASED LAYERS 1 Fog Formation 2 Fog Types (Including Mist) 3 Haze/Smoke 4 Blowing Obstruction to Vision	• Explain how fog is formed. • Identify the factors that can dissipate fog.
TURBULENCE 1 Convection 2 Mechanical 3 Orographic 4 Wind Shear	• Explain the sources of mechanical turbulence. • Describe the formation of turbulence around large objects and mountain tops.
WIND 1 Definition 2 Pressure Gradient 3 Deflection Caused by the Earth's Rotation 4 Low Level Winds – Variation in Surface Wind 5 Friction 6 Centrifugal Force 7 Veer/Back 8 Squall/Gusts 9 Diurnal Effects 10 Land/Sea Breezes 11 Katabatic/Anabatic Effects 12 Topographical Effects	• Explain the effect of pressure gradient and coriolis force on the horizontal movement of air. • Explain how wind changes in the friction layer. • Define wind shear and its effect on turbulence. • Explain the formation of land/sea breezes. • Use a picture to explain anabatic and katabatic winds.

AIR MASSES 1 Definition and Characteristics 2 Formation/Classification 3 Modification 4 Factors that Determine Weather 5 Seasonal/Geographic Effects 6 Air Masses Affecting North America	
FRONTS AND FRONTAL WEATHER 1 Structure 2 Types 3 Formation 4 Cross-sections 5 Frontogenesis/Frontolysis 6 Cold Front 7 Warm Front	• Discuss the relationship between air masses and creation of weather fronts. • Describe the changes in weather as a front approaches and passes over your location.
AIRCRAFT ICING 1 Formation 2 In-flight – Freezing Rain 3 Hoar Frost 4 Effect of frost and ice on launch and recovery systems	• Explain how icing is formed and the conditions that cause it. • Discuss the impact of having frost on flying surfaces.
THUNDERSTORMS 1 Requirements for Development 2 Structure/Development 3 Types – Air Mass/Frontal 4 Hazards – Updrafts/ Downdrafts/Gust Fronts/ Downbursts/Microbursts/Hail/ Lightning/Antennas 5 Squall Lines	• Describe the three stages of thunderstorm development. • Describe the surface weather characteristics of an approaching thunderstorm.

METEOROLOGICAL SERVICES AVAILABLE TO PILOTS 1 Flight Information Centres (FIC) 2 Aviation Weather Web Site 3 Pilot's Automatic Telephone Weather Answering Service (PATWAS) 4 Automatic Terminal Information Service (ATIS)	• Identify the sources for local weather information.
AVIATION WEATHER REPORTS 1 Decoding 2 Aviation Routine Weather Report (METAR) 3 Automated Weather Observation Station (AWOS) 4 Limited Weather Information System (LWIS)	• Compare reported weather with the SFOC limitations. • Demonstrate awareness of coded weather information, and identify methods of decoding. • Identify sources of weather reports (websites etc.).
AVIATION FORECASTS 1 Times Issued and Validity Periods 2 Decoding 3 Graphic Area Forecasts (GFA) 4 Aerodrome Forecasts (TAF) 5 Airman's Meteorological Advisory (AIRMET) 6 Significant In-flight Weather Warning Messages (SIGMET)	• Compare forecast weather with the SFOC limitations. • Assess forecast ceiling, wind, turbulence, precipitation and visibility against operational objectives. • Assess forecast vs. control station requirements (e.g. lightning). • Assess forecast and density altitude for anticipated performance and flight envelope limitations. • Demonstrate awareness and sources for AIRMETs and SIGMETs.

AERONAUTICS - GENERAL KNOWLEDGE

SECTION 4: AIRFRAMES, ENGINES AND SYSTEMS

Knowledge Areas	**Sample Learning Objectives** The pilot operating small UAVs within visual line of sight must be able to:
AIRFRAMES 1 Handling/Care/Securing	• Indicate how manufacturers identify the repairs and work that can be undertaken by the operator vs. what must be addressed by an authorized repair facility (e.g. how to find your applicable OEM guidelines). • Describe the importance of identifying propellor damage, surface contamination, wiring damage, structural damage. • Identify the parts of an airframe.
ENGINES 1 Two/Four Stroke Cycle 2 Methods of Cooling 3 Effects of Density Altitude/ Humidity 4 Limitations and Operations 5 Instruments and GCS information	• Identify the type of engine (2/4 stroke) or electric motor used on the UAV. • Explain the difference between 2 and 4 stroke engines/cycles.
ELECTRICAL SYSTEM 1 Typical Electrical System Components 2 Servo motors	• Describe typical electrical system components. • Describe the actions of a servo. • Describe the indications of a failed servo.
FUEL SYSTEMS AND FUELS 1 Types – Properties 2 Density/Weight 3 Additives 4 Contamination and Deterioration 5 Grounding/Bonding	• Discuss the importance of Material Safety Data Sheet in understanding fuel hazards. (note : this is comparably relevant to health and safety…)
DATA LINKS 1 Frequency bands (licensed and unlicensed) 2 Line-of-Sight	• Describe how to assess the RF environment or conduct and RF sweep. • List the parameters of a computer data port.

3 Antennas and tracking systems 4 Interference 5 Data protocols and data rates	• Discuss the importance of radio line-of-sight. • Discuss the importance of GCS antenna placement. • Discuss the causes of lost link and methods of recovery.
BATTERIES 1 Types and hazards 2 Battery parameters (Ah, voltage, charge and discharge rates (“C”)) 3 Battery configurations (parallel, series) 4 Charge cycles, storage, and maintenance 5 Discharge curves 6 Transportation of batteries (dangerous goods regulations)	• Interpret maintenance log history. • Describe the variables affecting batteries (capacity e.g. due to age, history, charge status). • Assess battery voltages (understand discharge curves) • Describe the regulations applicable to taking lithium-ion batteries on board a commercial flight.
AUTOPILOTS 1 The role of an autopilot 2 Software version control (GCS and UAV) 3 Different levels of control (e.g. stabilization vs. waypoint) 4 Flight termination systems (internal and remote)	• Describe the types of pilot intervention possible during flight. • Describe the re-flight preparation related to flight termination systems • Discuss the possible consequences of improper software version control.
PAYLOADS 1 sensor types (EO, IR, RF, atmospheric…infinite list)	• Define what comprises the payload vs. the rest of the system.
ELECTRIC MOTORS (propulsion) 1 Types of motors (brush, brushless, inrunner, outrunner) 2 Speed controllers	• Describe the characteristics of different motor types.
LAUNCH AND RECOVERY SYSTEMS 1 Types of launchers 2 Types of recovery systems 3 Safety areas and templates for launch and recovery	• Identify the different danger areas of a safety template.
MAINTENANCE AND RECORD KEEPING 1 Technical Log Requirements	• List the pilot`s requirements for record-keeping

SECTION 5: THEORY OF FLIGHT

Knowledge Areas	**Sample Learning Objectives** The pilot operating small UAVs within visual line of sight must be able to:
PRINCIPLES OF FLIGHT 1 Bernoulli's Principle 2 Newton's Laws	• Describe how lift is produced.
FORCES ACTING ON AN AEROPLANE 1 Lift 2 Drag– Induced/Parasite/Profile 3 Relationship of Lift and Drag to Angle of Attack 4 Thrust 5 Weight 6 Equilibrium 7 Centre of Pressure (C of P) 8 Centrifugal/Centripetal Forces 9 Forces Acting on an Aircraft during Manoeuvres	• Identify the 4 forces acting on an aeroplane in flight. • Describe how the 4 forces are balanced during manoeuvres and steady flight.
AEROFOILS 1 Pressure Distribution about an Aerofoil 2 Relative Airflow and Angle of Attack 3 Downwash 4 Wing Tip Vortices 5 Angle of Incidence	• Describe wingtip vorticies. • Define angle of attack, incidence, chord, etc. • Explain how lift is controlled.
PROPELLERS 1 Propeller Efficiency at Various Speeds 2 Propellor Handling/Care	• Describe how different propeller pitches affect aircraft performance.
DESIGN OF THE WING	• Describe how the design of the wing affects performance and

1 Wing Planform 2 Area/Span/Chord 3 Aspect Ratio 4 Camber 5 Dihedral/Anhedral 6 Spoilers 7 Flaps 8 Winglets	control response.
ROTOR DESIGN 1 Number / Speed of Blades 2 Rotor Blade Vortices 3 Limitations to Forward Speed and Vibrations 4 Autorotations 5 Tail Rotor	• Describe how lift is created with a rotary wing (powered and autorotation). • Describe how multiple rotors can be used for stability and control.
LOAD FACTOR 1 Centrifugal Force/Weight 2 Load Factor – Turns 3 Relationship of Load Factor to Stalling Speed (fixed wing) 4 Structural Limitations 5 Gust Loads	• Describe what can affect the load factor on an aircraft. • Explain that aircraft have structural limitations. • State that increasing the load factor produces a requirement for increased lift, thus producing increased drag.
STABILITY 1 Longitudinal, Lateral, Directional Stability 2 Inherent Stability 3 Methods of Achieving Stability, Effect of C of G Position	• Explain how the centre of gravity affects longitudinal stability.
AEROPLANE FLIGHT CONTROLS 1 Aeroplane Axes and Planes of Movement 2 Functions of Controls	• Explain the function of trim. • Describe the function of different control surfaces. • Explain how variations in airspeed change the effect of control

3 Relationship Between Effects of Yaw and Roll 4 Adverse Yaw/Aileron Drag 5 Trim	surface deflection.
HELICOPTER FLIGHT CONTROLS 1 Cyclic 2 Collective 3 Tail Rotor 4 Aids to Stability	• Describe how lift is controlled. • Describe the function of the tail rotor, counter-rotating rotors.
AIRCRAFT COMPONENTS 1 Rotor 2 Landing skid 3 Engine 4 Tail rotor 5 Tail boom 6 Stabilizer/elevator	• Identify the main/common components of rotary wing and fixed wing aircraft.
HELICOPTER AERODYNAMICS 1 Four Basic Forces 2 Blade Design 3 Pressure Distribution about an Aerofoil 4 Rotor Systems (Main/Tail) 5 Translational Lift/Flight 6 Transitions 7 Tail Rotor Drift/Roll 8 Theory of Autorotation and Flare 9 Reverse Flow 10 Blade Stall 11 Over Pitching 12 Settling with Power 13 Recirculation 14 Vortex Ring State	• Describe lift and collective control. • Describe the dangers of recirculating flow through a rotor. • Explain the hazard of loose surface cover when in ground effect.

15 Ground Effect	
MULTI-ROTOR COPTOR DYNAMICS	• Describe how flight is controlled in a multi-rotor helicopter.
AIRSHIPS	• State the advantages/disadvantages of airships.
RECOVERY SYSTEMS 1 parachute, deep stall, arresting system/hook, normal landing	• Explain the different methods employed to recover unmanned aircraft.

SECTION 6: FLIGHT INSTRUMENTS

Knowledge Areas	**Sample Learning Objectives** The pilot operating small UAVs within visual line of sight must be able to:
PITOT STATIC SYSTEM 1 Pitot 2 Static 3 Anti-Icing	• Describe a pitot-static system and the uses of the data. • Verify air data and inertial sensors.
AIRSPEED INDICATOR 1 Principles of Operation 2 Errors/Malfunctions 3 Definitions – IAS/CAS/TAS	• Explain the errors that occur with a blocked/faulty pitot-static system. • Explain the principles of operation of an Airspeed Indicator.
ALTIMETER 1 Principles of Operation 2 Errors/Malfunctions	• Explain the principles of operation of an Altimeter.
MAGNETIC COMPASS 1 Principles of Operation 2 Variation 3 Factors Adversely Affecting Compass Operation 4 Deviation	• Explain the difference between magnetic and true north. • Explain what can affect compass operation and reliability.
HEADING INDICATOR 1 Markings	• Determine aircraft heading.
ATTITUDE INDICATOR 1 Markings	• Determine aircraft attitude.

INSTRUMENT FLYING 1 Instrument Scan/Interpretation	• Interpret aircraft attitude/heading using instrument displays.
CONTROL STATION (CS) AND SIMULATION 1 File management a. Operating system and environment b. Physical connectivity c. Configuration management (hardware, software, operating system) 2 Diagnostics and test	• Explain that different configurations may require changes in software/database. • Describe the main aspects of configuration management of the CS computer (operating system, software version). • Explain the importance of pre-flight diagnostics and tests. • Explain how simulation can be used to verify the flight plan and map data.

SECTION 7: FLIGHT OPERATIONS

Knowledge Areas	**Sample Learning Objectives** The pilot operating small UAVs within visual line of sight must be able to:
GENERAL 1 Pilot-In-Command Responsibilities 2 Aircraft Defects 3 Winter Operations 4 Thunderstorm Avoidance 5 Mountain Flying Operations 6 Wildlife Hazards 7 Wildlife Conservation 8 Collision Avoidance – Use of Lights 9 Runway Numbering 10 Aerodrome Operations (Procedures for the Prevention of Runway Incursions and conflicts) 11 Taxiing, Hover taxi 12 Radio/Electronic Interference, Portable Electronic Devices	• Describe the hazards that can occur in different geographic or topographical areas. • Describe the normal flow of manned aircraft traffic at an aerodrome (circuit, taxiing, etc.). • Explain how local and portable devices might be controlled to reduce interference.
AIRCRAFT PERFORMANCE 1 Lift/Drag Ratio 2 Effects of Density Altitude/ Humidity 3 Best Angle of Climb (V_x) .4 Best Rate of Climb (V_y) 5 Cruising SpeedMaximum Normal Operating Speed (V_{no}) 6 Never Exceed Speed (V_{ne}) 7 Flying for Range 8 Flying for Endurance 9 Stalls 10 Spins	• Explain the importance of lift/drag ratio on climb and glide performance. • Describe the effect of density altitude on launch and climb performance. • Describe situations where best angle of climb and best rate of climb should be used. • Describe how speed affects range and endurance. • Describe the effect of airspeed on radius of turn. • Explain the need for an operating margin above stall speed (turbulence and turns). • Determine parachute recovery drift distance based on altitude

11 Bank/Speed vs Rate/Radius of Turn 12 Use of Aircraft Flight Manual 13 Parachute Recovery performance 14 Deep Stall Recovery performance	and wind.
PERFORMANCE CHARTS/DATA 1 Launcher Charts 2 Cross-wind Limits 3 Factors affecting Performance (battery, wind, speeds, climb power, etc) 4 (V) Speeds – V_a, V_{no}, V_{ne}, V_s, V_x, V_y 5 Factors affecting Launcher Performance (Ice,Temperature) 6 Effect of Various Runway Surfaces on Take-off and Landing Run 7 Hover ceiling, in and out of Ground Effect	• Describe the effect of temperature on bungee cord launchers. • Identify cross-wind limits. • Explain the relationship between climb height and remaining power/fuel. • Explain how runway surface affects takeoff performance.
WEIGHT AND BALANCE 1 Terms – e.g. Datum/Arm/ Moment 2 Locating CG 3 CG Limits 4 Weights – e.g. Empty/Gross 5 Load Adjustment	• Describe methods of determining Centre of Gravity. • Describe how to return a C of G to within limits.
AIRCRAFT CRITICAL SURFACE CONTAMINATION 1 Effects of Aircraft Critical Surface Contamination on Performance 2 Types of Contaminants (water, frost, snow, condensation, duct tape)	• Recognize weather conditions that can cause surface contamination. • Describe the effects of surface contamination on airfoils
EXTERNAL LOADS 1 Effect on stability and performance	• Describe the effect of slung loads on stability.
OCCUPATIONAL SAFETY AND HEALTH	• List the safety equipment necessary for the operation (fire

1 Equipment 2 Weather 3 Communications 4 Operating Area 5 People	extinguisher, first aid, etc.). • Assess weather threats vs. ground station operations. • Identify and evaluate access routes • Assess public access and determine crowd control requirements • List typical emergency contacts appropriate to flying site (flyaways, EMS etc.) • Identify legal site access issues (landowner permission). • List typical personal safety equipment. • Describe the hazards of launchers and recovery systems.

UAV VLOS OPERATIONS
1 Fueling areas, charging areas
2 Launch Points, Recovery Points
3 Obstacles
4 Emergency Procedures
5 Responsibilities
6 Communications
7 Post Flight Actions
	• Identify typical functional areas in a VLOS site (e.g. launch, observer)
	• Identify desirable characteristics of alternate recovery areas
	• Identify the requirements of visual observer locations
	• List the typical items is a crew briefing
	  o Orientation (north etc)
	  o Who is doing what
	  o Mission objectives and plan
	  o Operational timeline
	  o Aircraft performance limitations (density altitude, temperature etc)
	  o Emergency procedures
	  o Airspace conflicts and avoidance maneuvers (manual or pre-programmed)
	  o Flyaways
	  o Public interference procedure
	  o Recovery area
	  o Communicate procedures with any clients, public etc. at the operation
	  o Identify the Ground Supervisor
	  o Safe areas
	  o Expectations of what the crew will observe
	  o EM (cell phone) restrictions

	○ “clean cockpit” (e.g. no interferences or distraction with the crew) ○ Roles and responsibilities if a client is interacting with the pilot or crew • Check for all crew and bystanders in safe position (pre-takeoff) • Communicate who has control and direction of crew • Describe the launch sequence when using a launcher • Describe the launch sequence when hand launching. • Describe the take-off sequence when ground launching. • Identify the typical communications that take place during VLOS operations taking off from the ground ○ Communicate countdown and take-off command ○ Emergency abort communications (e.g. radio silence) ○ Communicate any transfer of control immediately after takeoff (e.g. manual to computer control) ○ Communicate abort in the event of any abnormal flight behavior or equipment behavior ○ Communicate status of takeoff to the crew ○ Pass all air traffic contact to flight crew ○ Communicate aircraft progress and expected manoeuvers (pilot to crew members) ○ Communicate visual contact status and visual handoffs (crew to crew and crew to pilot) ○ Communicate with clients who have a role in directing the flight • Describe Emergency procedures ○ Airspace conflicts and avoidance maneuvers (manual or pre-programmed) ○ System faults (GPS etc.) ○ Lost link ○ Flyaways ○ Abnormal behaviours (evaluate, respond, troubleshoot) e.g. Is it a downdraft or a command anomaly or a

	mechanical failure? ○ Public interference • Operate according to checklists • Other procedures per SOPs and system manual (need to teach appreciation of the problem and some examples) • List recommended post-flight actions. ○ Download data (post-flight) ○ Check for damage ○ Clean and dry as needed ○ Remove excess fuel (as applicable) ○ Remove batteries (as applicable) ○ Record information to data logs ○ Disassemble and pack per system manual ○ Aircraft ○ GCS ○ Launcher ○ Landing system

SECTION 8: HUMAN FACTORS

Knowledge Areas	**Sample Learning Objectives** The pilot operating small UAVs within visual line of sight must be able to:
AVIATION PHYSIOLOGY 1 Vision/Visual Scanning Techniques 2 Hearing 3 Orientation/Disorientation (Including VisualPerspective/Parallax Illusions) 4 Body Rhythms/Jet Lag 5 Sleep/Fatigue 6 Anaesthetics	• Describe good scanning techniques (visual, audio) for visual observers (conflicting aircraft). • Describe “Perspective Illusion” when looking at distant aircraft. • Describe factors that affect alertness.
THE PILOT AND THE OPERATING ENVIRONMENT 1 Medications (Prescribed and Over-the-counter) 2 Substance Abuse (Alcohol/ Drugs) 3 Heat/Cold 4 Noise 5 Toxic Hazards (Including Carbon Monoxide – GCS vehicle)	• Describe the effects of a hangover on pilot performance. • Describe the effects of exposure to cold and excessive heat on pilot performance. • Describe the symptoms of carbon monoxide poisoning.
AVIATION PSYCHOLOGY 1 Factors That Influence Decision-Making 2 Situational Awareness 3 Stress 4 Managing Risk 5 Attitudes 6 Workload – Attention and Information Processing	• List factors that interfere with effective decision-making. • List the factors that affect situational awareness. • Describe how a given operational risk might be managed.
PILOT – EQUIPMENT/MATERIALS RELATIONSHIP	• Explain the benefits of Standard Operating Procedures and

1 Controls and Displays – Errors in Interpretation and Control 2 Standard Operating Procedures – Rationale/Benefits 3 Correct Use of Check-lists and Manuals 4 Automation and complacency	Lessons Learned. • Explain how to manage an interruption to a checklist.
INTERPERSONAL RELATIONS 1 Communications with Flight Crew/Maintenance Personnel/Air Traffic Services/Passengers 2 Operating Pressures – Family Relationships/Peer Group 3 Operating Pressures – Employer	• Resolve differences peacefully. • Promote open communications. • Place safety requirements over hierarchy/position in organization/politics.

RADIOTELEPHONY

Knowledge Areas	**Sample Learning Objectives** The small UAV pilot operating Visual Line of Sight must be able to:
AERONAUTICAL RADIO-TELEPHONE COMMUNICATIONS 1 Operator's Certificate (Aeronautical) - (ROC-A course) 2 Terminology 3 Common frequencies 4 Emergencies	• Interpret aeronautical radiocommunication (position, phase of flight) • Communicate using standard radio terminology. • Give an example of a routine blind broadcast. • List the contents of a routine call to ATC . • Give an example of an emergency (flyaway) broadcast.
GROUND CREWMEMBER RADIOS 1 Terminology 2 Reception performance	• Give an example of an advisory describing a possible aircraft conflict. • Describe factors affecting radio reception range.

ENQUIRIES

Information concerning the operation of small UAVs and pilot certification may be obtained by contacting the appropriate Regional Offices. A complete listing may be found at: http://www.tc.gc.ca/eng/regions-air.htm.

RECOMMENDED STUDY MATERIAL

- Transport Canada Staff Instruction SI 623-001 – The Review and Processing of an Application for a Special Flight Operations Certificate for the Operation of an Unmanned Air Vehicle (UAV) System
- Air Command Weather Manual (TP 9352)
- Human Factors for Aviation - Basic Handbook (TP 12863), and Advanced Handbook (TP 12864)
- Transport Canada Aeronautical Information Manual (TC AIM) (TP14371) http://www.tc.gc.ca/civilaviation/publications/tp14371/menu.htm
- *Canadian Aviation Regulations* (CARs) http://laws-lois.justice.gc.ca/eng/regulations/SOR-96-433/index.html
- VFR Navigation Charts (VNC)/VFR Terminal Area Charts (VTA)
- Canada Flight Supplement

Transport Canada publications (TP) may be purchased from retailers, or at the following web site: http://www.tc.gc.ca/eng/civilaviation/publications/menu.htm

The Study Guide For The Radiotelephone Operator's Restricted Certificate - Aeronautical (RIC-21) is available free of charge from district offices of Industry Canada - Examinations and Radio Licensing (http://www.strategis.gc.ca).

Information on the Transportation of Dangerous Goods is available from Transport Canada. http://www.tc.gc.ca/eng/tdg/safety-menu.htm

The Canada Labour Code is available from Justice Canada (http://laws-lois.justice.gc.ca/eng/acts/L-2/

Information on text books and other publications produced by commercial publishers can be obtained through local flying training organization, bookstores and similar sources.

Publications used in pilot training in the United States are available through the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (http://www.access.gpo.gov/index.html).