Software Design Document – Draft 1
LIDAR Level 0 (HDF) and Level 1A files generation process

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Introduction

The procedures for the Version 3 LIDAR Level 1 processing includes three passes in the same PGE:

1. The first pass reads the three channels Level 0 (L0) data, unpacks the packets, and matches the three channels data with time. Normalizes the raw data with gain value and laser energy. Performs the altitude registration to update the profile location and satellite location. Sets the DEM parameters. Calculates the 532 nm nighttime calibration coefficients for every 165 profiles (5 km). Smooths the 532 nm calibration coefficients for every 27 values. Output the parameters to two temporary HDF files, one is for nighttime and one is for daytime.

   The first pass stops when it obtains the second smoothed 532 nm nighttime calibration coefficients of the second nighttime orbit.

   At the end of the first pass, calculate the noise scale factors that are only available for daytime orbit. Setup the 532 nm calibration coefficients table with the averaged previous nighttime calibration coefficients.

2. The second pass reads the data from the temporary HDF files for calculating the 1064 nm calibration coefficients. This calculation requires the 532 nm calibration coefficients from the first pass. It calculates the nighttime and daytime separately. It calculates one mean factor for the nighttime and one mean value for the daytime.

3. The third pass calculates the attenuated backscatter values with the new three channels calibration coefficients. Calculate the satellite positions and met parameters such as temperature, pressure… Write to the final output products.

The data required for the 532 nm nighttime calibration coefficients smoothing is using one nighttime orbit only.

However, it has been found that the assumption of low amount of aerosol in the current calibration region (30 – 34 km) is not valid in the tropics because it has been found significant amounts of aerosols can be presented up to 35 km. Therefore, it can lead to a significant error for calculating the 532 nm nighttime calibration coefficients in the tropics. Therefore a new approach is applied to the 532 nm nighttime calibration coefficient calculation;

1. The location of the baseline region will move higher than the current location (30 – 34 km). Based on SAGE II, the range from 36 to 39 km is almost complete absence of aerosols, so the new calibration region is set to 36 – 39 km.

2. To maintain the current calibration SNR at the new region is required to average over several consecutive nighttime granules, so the new procedure will use more than one orbit calibration coefficients to do smoothing.

Since the new proposed smoothing procedure requires more than one nighttime orbit of 532 nm calibration coefficients, the portion for the 532 nm nighttime calibration coefficient calculations is extracted out from the LIDAR Level 1B processing to become "preprocessing". Similarly, the 1064 calibration coefficient calculation is also changed to require more than one orbit data, therefore, the new LIDAR Level 1 processing is breaking into several PGEs:

1. Level 0 HDF files and Level 1A files generating
2. Pre-Level 1B files generating
3. 532 nm nighttime calibration coefficient calculation
4. 532 nm scattering ratio calculation (for daytime)
5. 1064 nm calibration scale factors calculation
6. Calibration averaging
7. Post-processing

This design document is for the Level 0 HDF files and Level 1A files generation PGE.

The LIDAR L0 raw data files are in CCSDS packet format. These files are binary files and are not easy to read and access. Some words (2 bytes) in each packet are combined with several flags, and some parameters are in counts that required converting to engineering units so that users can understand. Moreover, each channel (3 channels; 532 nm parallel, 532 nm perpendicular, and 1064 nm) has its own input file. Therefore, the first process of the LIDAR Level 1 is converted these binary L0 files (three files) into one HDF4 file with matching the 3 channels data into one file (L0 HDF file). This process only requires the coefficient conversion ancillary input files and they are static files. This process can be started immediately when these binary L0 files arrive at ASDC.

The generating Level 1A (L1A) process applies the Level 1A correction and normalizes the raw data with the laser energy and variable gain to the 3 channel raw data. This process is similar with the generating L0 process; it only requires the L1A correction coefficients ancillary input file, which is a static file.

Since these two processes do not require any dynamic input files, they can be put into same PGE. The input files are three channel L0 data file (90 minutes data) and the output files are also with the same amount data (90 minutes).

Section 1 – The purpose of the LIDAR Level 0 HDF and Level 1A files generation process

The purpose of the LIDAR Level 0 HDF and Level 1A files generation PGE is processing the raw data reported in the binary L0 files into engineering units that users can understand the data and use them for their studies. The data stored in the binary L0 data files are in CCSDS packet format that most of the data are packed into two-bytes words and in counts. Before users can access and understand the data, these data are required to unpack and convert to user understandable engineering units. All the unpacked data in the binary L0 data are written into the HDF L0 data. After the raw sample data perform with the Level 1A correction and normalizing with the laser energy and variable gain, the data required for downstream PGEs, such as Level Pre-Level 1B, calibration coefficients, …, are written to the Level 1A file. Since both Level 0 HDF and L1A contain same amount of data, 90-minutes, both processes are put in the same PGE.

Section 2 – The high level entities of design

The top level of flow chart for this PGE is showed on the Figure 1.

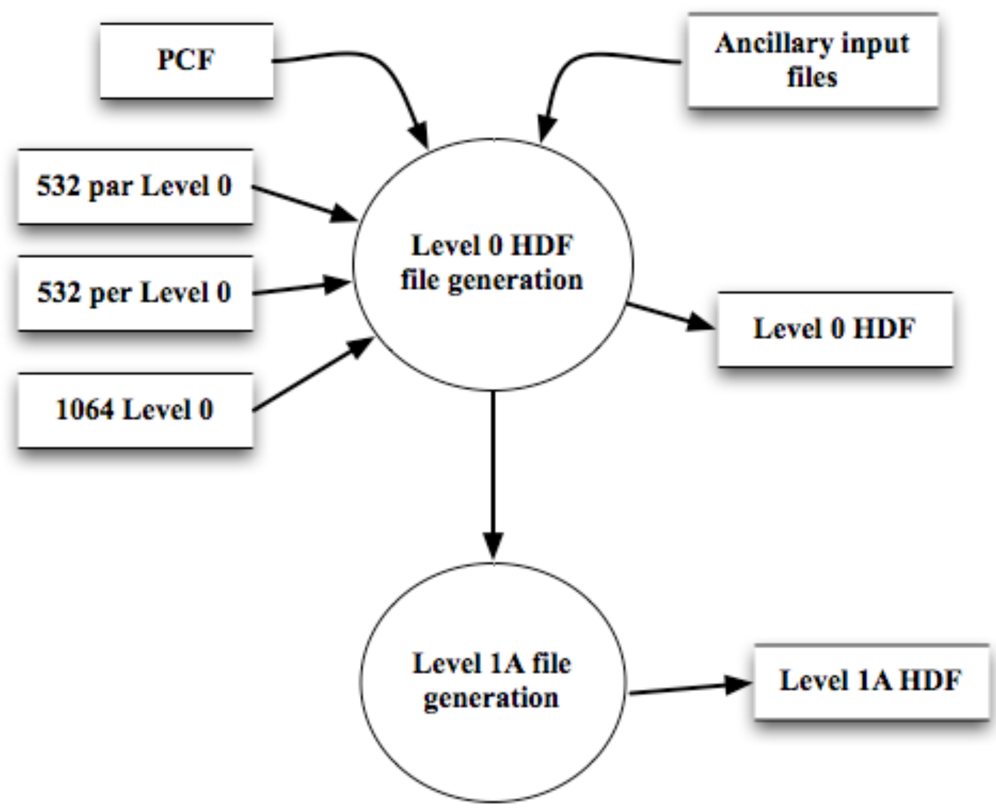

Figure 1 LIDAR Level 0 and Level 1A process

When the L0 data files are arrived at DAAC, the CAPS can generate the PCF file that control the process and start the PGE to generate the L0 HDf file and L1A file. The input files are the three channels (532 nm parallel, 532 nm perpendicular, and 1064 nm) L0 data files and the count conversion coefficients for laser energy, variable gain, and background monitor data. The flow chart for this PGE is shown in the Figure 2.

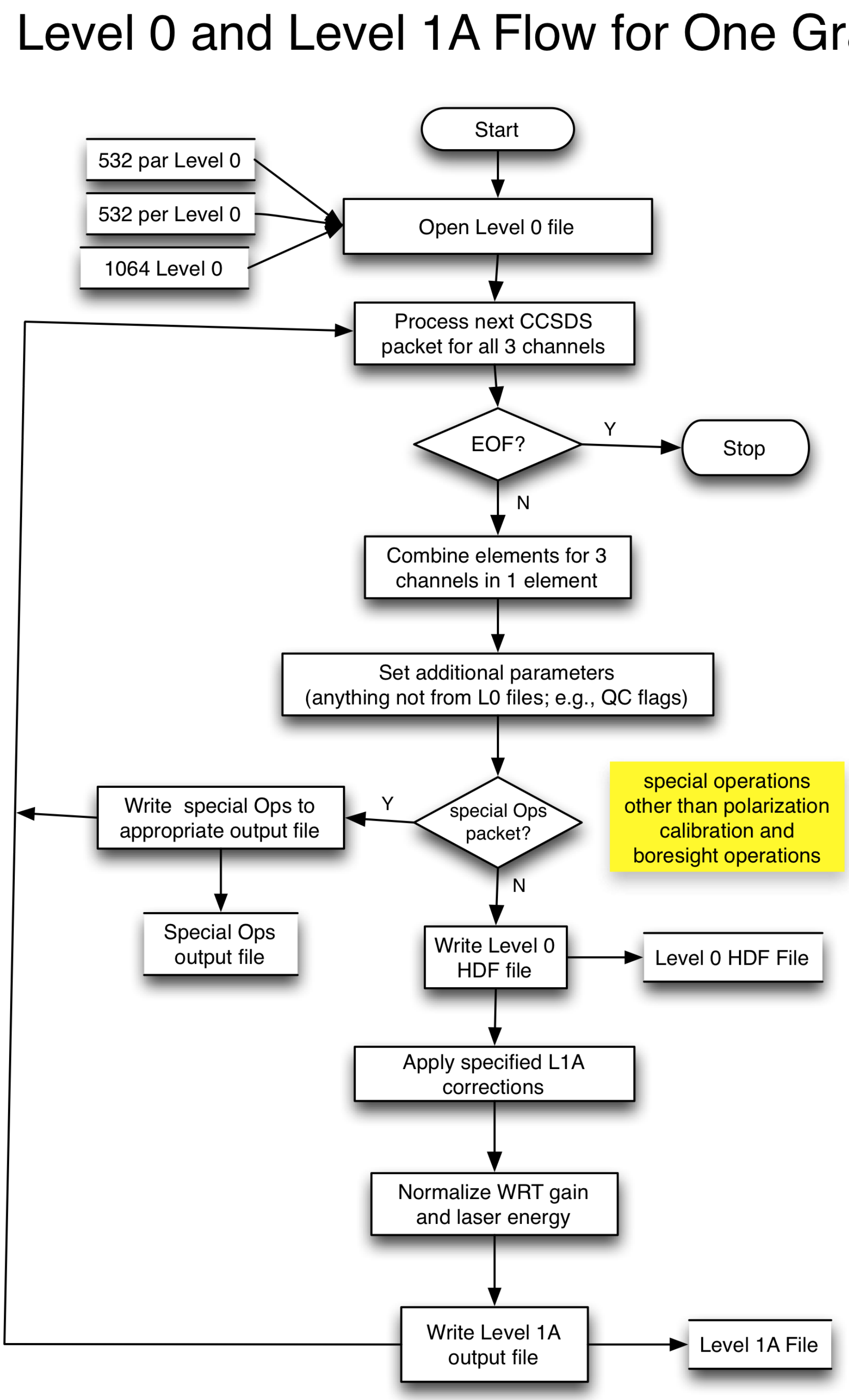

Figure 2 Generating L0 HDF and L1A files flowchart

The procedures for this processing include opening the three channel L0 files and unpacking the packets. Based on the packet time stamp and frame number, it calculates the profile time for each profile. It breaks one mayor frame (5km) to 15 individual profiles (records). It converts the parameters in 16-bit Float Number to 32-bits float number and converts parameters in counts, such as laser energy, variable gain, and background monitor, into engineering units.

The next step is to match the three channel records with time and combine these three elements (records) into one element (record). It puts all the parameters into the combined record. It then verifies the quality of the L0 data based on the information stored in the L0 records and sets the quality flags. It also sets the missing packet bit if any channel is missing. If the LIDAR mode and submode indicate this a special operation packet, it writes the record to a special output file, otherwise, it writes the record to the L0 HDF output file.

The process continues with applying L1A correction and sample data are normalized with the laser energy and variable gain. The parameters specified for the L1A output files are written to output file.

One L0 HDF file and L1A file contain the same amount data of the input L0 binary files; 90 minutes. For this process, it depends on only one 90-minute input L0 file (3 channels), so each 90-minute input L0 file can be processed simultaneaously.

Section 3 – The low level entities of design

This PGE is part of the Version 3 LIDAR Level 1 process, so some of the codes from the current codes can be reused with some modification. Figure 3 shows the Version 3 LIDAR Level 1 processing. Comparing with the Figure 2, the L0 HDF file process can reuse these modules:

1. Lidar532ParMappingAlgorithm
2. Lidar532PerMappingAlgorithm
3. Lidar1064MappingAlgorithm
4. MatchPacketTimes
5. Combine532Par532Per1064
6. SetAdditionalParameters
7. createL0HDFFile

And the L1A file process can reuses these modules:

1. LidarLevel1aCorrections
2. NormalizeData
3. SetQAFlags

The three MappingAlgorithm modules are for unpacking and converting of the data stored in the L0 records. The MatchPacketTimes and Combine532Par532Per1064 modules are for matching 3 channels data records and combining into one record. The SeAdditionalParameters is for extracting quality flags and day/night flag. The createL0HDFFile is for creating L0 HDF file.

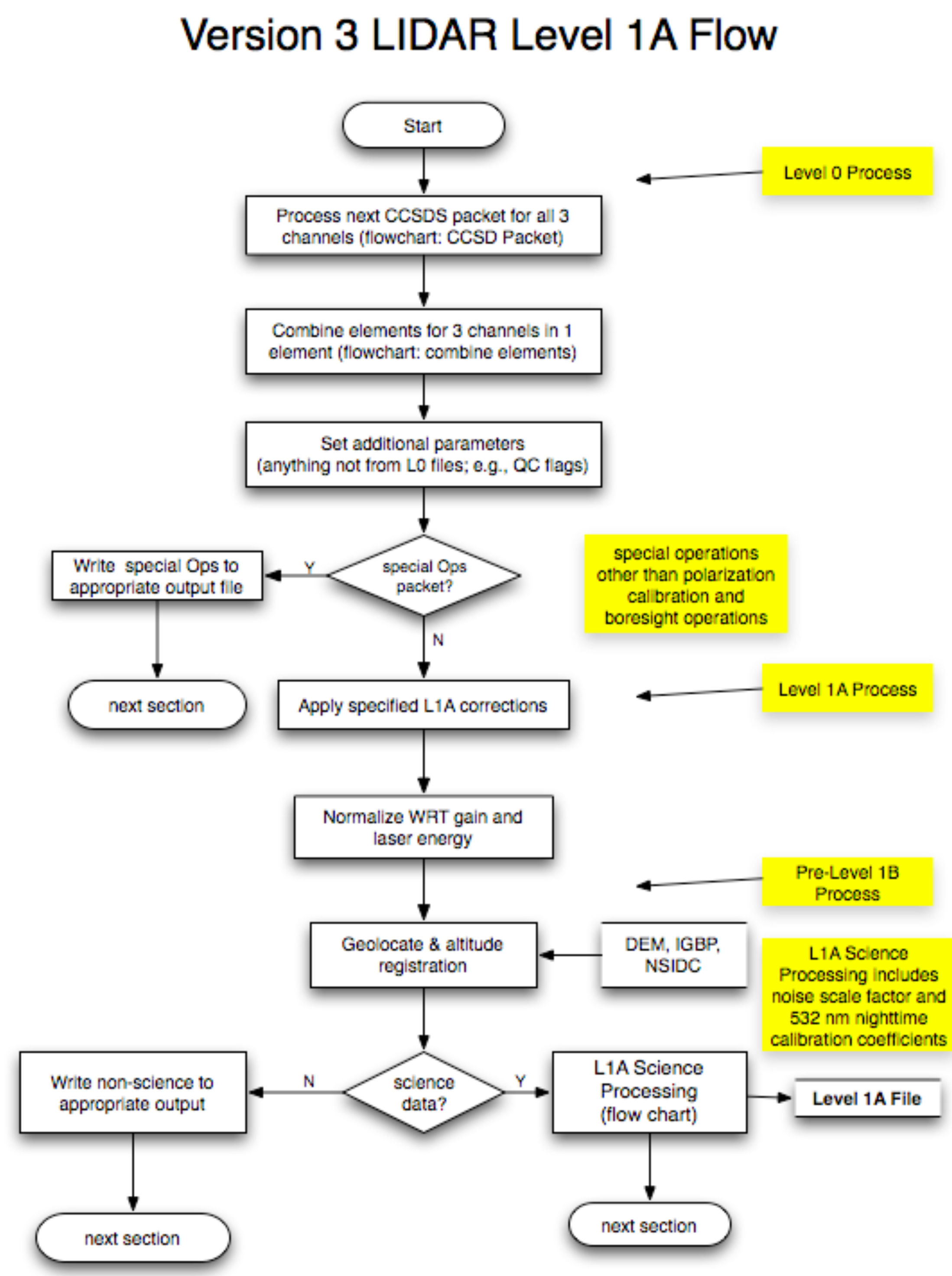

Figure 3 Version 3 LIDAR Level 1 processing

The LidarLevel1aCorrections module is for applying the L1A correction to the signal data. The NormalizeData module is for normalizing signal data with the laser energy and variable gain. The SetQAFlags module is for verifying the quality of the signal that stored in the L0 records.

The following sections describe each of these modules.

3.1 Lidar532ParMappingAlgorithm, Lidar532PerMappingAlgorith, Lidar1064MappingAlgorithm

These modules are for unpacking the L0 records for the 3 different channel data. Since each channel has its own parameter names and different formats, it requires each channel has its own module. The Figure 4 shows the flow chart of this module. The flow is same as for all three channels.

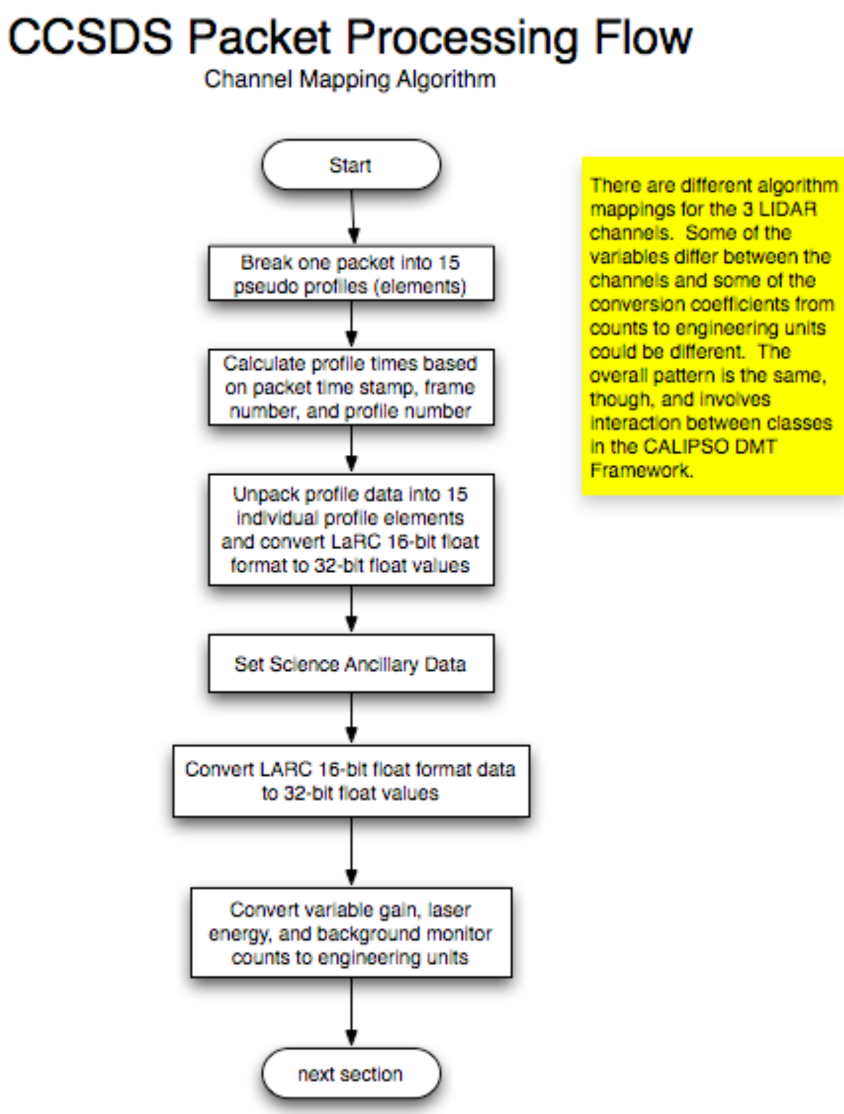

Figure 4 Flow chart for MappingAlgorithm

This module breaks one major frame (one record with 15 profiles) into 15 individual profiles (15 elements) from the downlink resolution. It calculates the profiles based on the packet time stamp and the frame number. The interval between two frame is 0.744 seconds; the interval between two profiles is 0.0496 seconds. If the parameters are in LaRC 16-bit float format, it converts it to 32-bit float number. If the parameters are required to convert to engineering units from count, it converts them. It retrieves the science ancillary data (SAD) and quality of the data from the L0 records.

3.2 MatchPacketTimes and Combine532Par532Per106

This module is to match the three channel records with time and combine all three channels records into one record. The Figure 5 shows the flow chart for the MatchPackettimes module. It compares the profile times for the current 3 channels records. If any one or two do not match, it checks which channel data is (are) missing and set the missing channel data with a default record in which all the sample data are set to fill value (-9999). It also sets the profile time with the current time.

Once all three channels data are matched, it combines all the three different records into one records. It starts the 532 nm parallel record if it is not a missing record. If 532 nm parallel is missing, it uses the 532 nm perpendicular. If both 532 nm channels are missing, it uses the 1064 nm channel data. It copies all the parameters in the channel record into the combined record, and then the other two channels data. It skips the parameters that already are copied into the combined record.

3.3 SetAdditionalParameters and createL0HDFFile

The SetAdditionalParameters module adds the parameters that are recorded in the L0 records, such as the historical calibration values that may require for calculation. Set the instrument mode and submode. It retrieves the day/night from a combined flag. It also applies the Day/Night Gain Ratio correction for the gain values. It also setup the fill element that is used for missing packet.

The createL0HDFFile module is using the OutputManager to write the L0 data record (element) to the L0 HDF output file. The parameters will be written to the L0 HDF file are specified in the output configuration file.

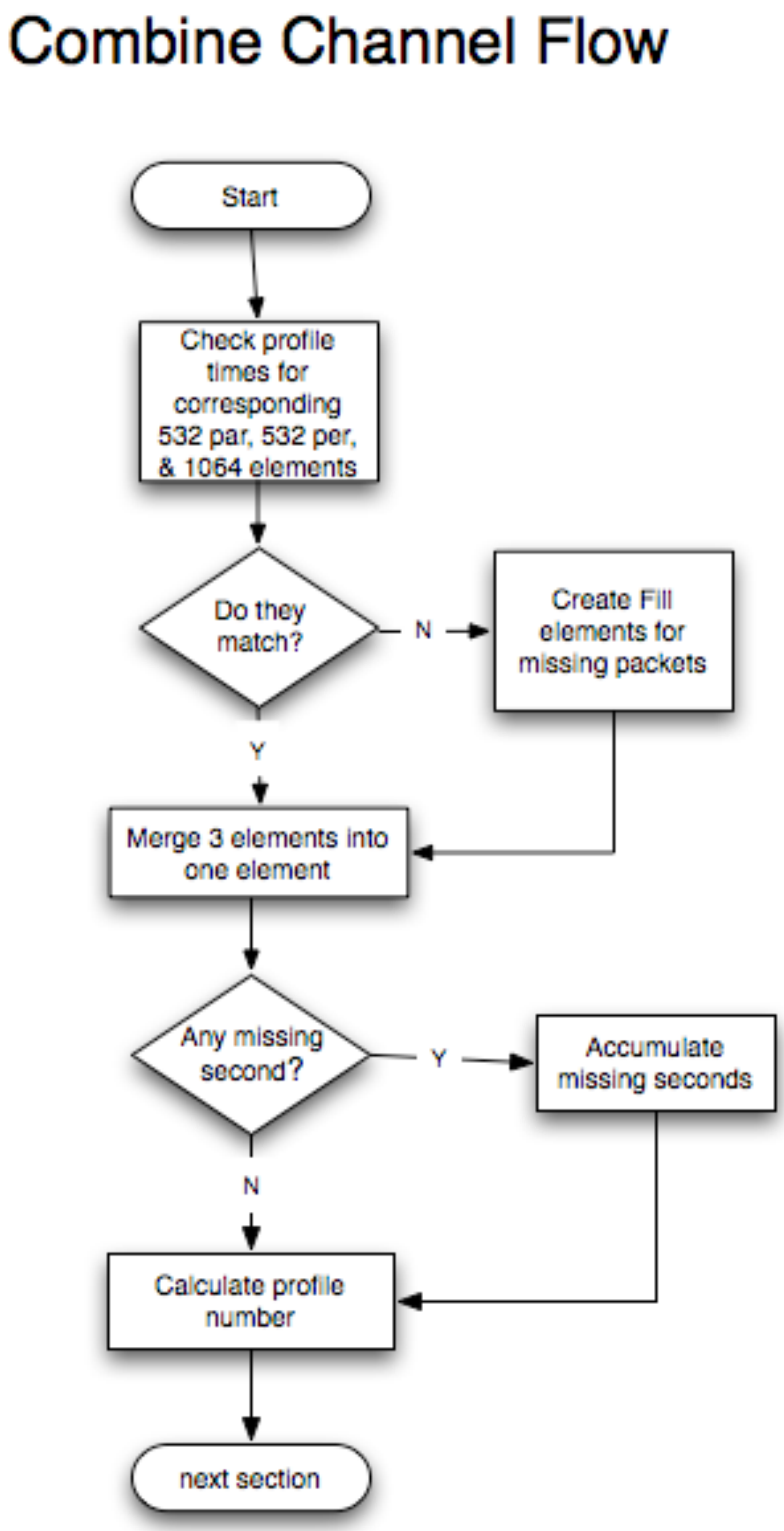

Figure 5 Flow chart for MatchPacketTime

3.4 LidarLevel1aCorrection

The LidarLevel1aCorrection module applies the Level 1A corrections. There are three types of corrections; 1 Baseline shape correction, 2 Baseline slope correction, and 3 Detector Gain Change with Background correction. A runtime parameter is set in the PCF file to determine which correction(s) to perform. These corrections are based on input coefficients from L1A correction input file.

3.5 NormalizeData

The NormalizeData module normalizes the signal data with the laser energy and variable gain vlues that stored in the L0 record. The way to normalize with laser energy is same as the downlink resolutions. It uses 5 different regions to average the laser energy. The region 5, it uses average of 15 profiles; region 4, it uses 5 profiles; region 3, it uses 3 profiles; region 2 and 1 use single profile. It also checks the quality of the laser energy. If the laser energy values are less than the threshold, it set the quality flag to indicate it.

3.6 SetQAFlags

The SetQAFlags module verifies the quality of the signal data reported in the record. The quality checks include the underflow and overflow signals and the root mean square noise. The results are set in the QC_Flag_2. The thresholds for all the parameters are stored in an input HDF file.

3.7 writeL1AFile

The writeL1AFile module uses the OutputManager to write the specified parameters to the L1A file. The specified parameters are set in a L1A output configuration file.

Section 4 – Input and Output records

The input files are L0 binary files. The contents of these files are described in the DRD-14. It will not given here. If one would like to get more information, he/she can review this document.

The output record for the L0 HDF file is given as in Table 1:

Table 1: LIDAR L0 Record

Parameter Name	Data Type	Elem/Rec
Profile_Time (TAI time)	Float_64	1
Profile_UTC_Time (yyyymmdd.ffffff)	Float_64	1
Profile_ID	Int_32	1
Day_Night_Flag	Int_8	1
QC_Flag	Uint_32	1
Lidar_Mode	Int_16	1

Parameter Name	Data Type	Elem/Rec
Lidar_Submode	Int_16	1
Frame_Number	Int_16	1
PMT_Parallel_Box_Temp	Uint_16	1
PMT_Perpendicular_Box_Temp	Uint_16	1
APD_Post_Amp_Temp	Uint_16	1
LRE_ADC_Temp	Uint_16	1
Laser_Radiator_Temp	Uint_16	1
Telescope_Primary_Mirror_Temp_1	Uint_16	1
Telescope_Primary_Mirror_Temp_2	Uint_16	1
Optical_Bench_Temp_2	Unt_16	1
Etalon_1_Temp	Uint_16	1
Etalon_2_Temp	Uint_16	1
APD_Heater_Temp	Uint_16	1
Parallel_Amplifier_Gain_532	Float_32	1
Perpendicular_Amplifier_Gain_532	Float_32	1
Amplifier_Gain_1064_High	Float_32	1
Amplifier_Gain_1064_Low	Float_32	1
High_Gain_ADC_Offset_532_Par	Uint_16	1
Low_Gain_ADC_Offset_532_Par	Uint_16	1
High_Gain_ADC_Offset_532_Per	Uint_16	1
Low_Gain_ADC_Offset_532_Per	Uint_16	1
High_Gain_ADC_Offset_1064	Uint_16	1
Low_Gain_ADC_Offset_1064	Uint_16	1
Laser_Energy_Monitor_532	Float_32	1
Laser_Energy_Monitor_1064	Float_32	1
Parallel_Background_Monitor_532	Float_32	1
Perpendicular_Background_Monitor_532	Float_32	1
Lidar_Receiver_Electronics_Status_532_Par	Uint_32	1
Lidar_Receiver_Electronics_Status_532_Per	Uint_32	1
Lidar_Receiver_Electronics_Status_1064	Uint_32	1
Active_Laser_Number	Uint_16	1
HVPS_Output_Monitor_532_Par	Uint_16	1
HVPS_Output_Monitor_532_Per	Uint_16	1
HVPS_Output_Monitor_1064	Uint_16	1
Dynode_Current_Monitor_532_Par	Uint_16	1
Dynode_Current_Monitor_532_Per	Uint_16	1
Quality_Flags_532_Par	Uint_16	1
Quality_Flags_532_Per	Uint_16	1
Quality_Flags_1064	Uint_16	1
Laser_Latitude	Float_32	1
Laser_Longitude	Float_32	1
Range_To_Mean_Sea_Level	Float_32	1
Backscatter_Start_Altitude	Float_32	1
Region_6_Low_Gain_Raw_Mean_532_Par	Float_32	1
Region_6_Low_Gain_Raw_Mean_532_Per	Float_32	1

Parameter Name	Data Type	Elem/Rec
Region_6_Low_Gain_Raw_Mean_1064	Float_32	1
Region_6_Low_Gain_Frame_RMS_Noise_532_Par	Float_32	1
Region_6_Low_Gain_Frame_RMS_Noise_532_Per	Float_32	1
Region_6_Low_Gain_Frame_RMS_Noise_1064	Float_32	1
Region_6_Low_Gain_Overflows_532_Par	Uint_16	1
Region_6_Low_Gain_Overflows_532_Per	Uint_16	1
Region_6_Low_Gain_Overflows_1064	Uint_16	1
Region_6_Low_Gain_Underflows_532_Par	Uint_16	1
Region_6_Low_Gain_Underflows_532_Per	Uint_16	1
Region_6_Low_Gain_Underflows_1064	Uint_16	1
Region_3_Low_Gain_Raw_Mean_532_Par	Float_32	1
Region_3_Low_Gain_Raw_Mean_532_Per	Float_32	1
Region_3_Low_Gain_Raw_Mean_1064	Float_32	1
Region_2_Low_Gain_Overflows_532_Par	Uint_16	1
Region_2_Low_Gain_Overflows_532_Per	Uint_16	1
Region_2_Low_Gain_Overflows_1064	Uint_16	1
Region_1_Low_Gain_Overflows_532_Par	Uint_16	1
Region_1_Low_Gain_Overflows_532_Per	Uint_16	1
Region_1_Low_Gain_Overflows_1064	Uint_16	1
Region_0_Low_Gain_Raw_Mean_532_Par	Float_32	1
Region_0_Low_Gain_Raw_Mean_532_Per	Float_32	1
Region_0_Low_Gain_Raw_Mean_1064	Float_32	1
Region_6_High_Gain_Raw_Mean_532_Par	Float_32	1
Region_6_High_Gain_Raw_Mean_532_Per	Float_32	1
Region_6_High_Gain_Raw_Mean_1064	Float_32	1
Region_6_High_Gain_Frame_RMS_Noise_532_Par	Float_32	1
Region_6_High_Gain_Frame_RMS_Noise_532_Per	Float_32	1
Region_6_High_Gain_Frame_RMS_Noise_1064	Float_32	1
Region_6_High_Gain_Overflows_532_Par	Uint_16	1
Region_6_High_Gain_Overflows_532_Per	Uint_16	1
Region_6_High_Gain_Overflows_1064	Uint_16	1
Region_6_High_Gain_Underflows_532_Par	Uint_16	1
Region_6_High_Gain_Underflows_532_Per	Uint_16	1
Region_6_High_Gain_Underflows_1064	Uint_16	1
Region_3_High_Gain_Overflows_532_Par	Uint_16	1
Region_3_High_Gain_Overflows_532_Per	Uint_16	1
Region_3_High_Gain_Overflows_1064	Uint_16	1
Region_2_High_Gain_Overflows_532_Par	Uint_16	1
Region_2_High_Gain_Overflows_532_Per	Uint_16	1
Region_2_High_Gain_Overflows_1064	Uint_16	1
Region_6_Merged_Background_Mean_532_Par	Float_32	1
Region_6_Merged_Background_Mean_532_Per	Float_32	1
Region_6_Merged_Background_Mean_1064	Float_32	1
Region_6_Merged_Shot_RMS_Noise_532_Par	Float_32	1
Region_6_Merged_Shot_RMS_Noise_532_Per	Float_32	1

Parameter Name	Data Type	Elem/Rec
Region_6_Merged_Shot_RMS_Noise_1064	Float_32	1
Region_5_Merged_Backscatter_Mean_532_Par	Float_32	1
Region_5_Merged_Backscatter_Mean_532_Per	Float_32	1
Region_4_Merged_Backscatter_Mean_532_Par	Float_32	1
Region_4_Merged_Backscatter_Mean_532_Per	Float_32	1
Region_4_Merged_Backscatter_Mean_1064	Float_32	1
Region_3_Merged_Backscatter_Mean_532_Par	Float_32	1
Region_3_Merged_Backscatter_Mean_532_Per	Float_32	1
Region_3_Merged_Backscatter_Mean_1064	Float_32	1
Region_2_Merged_Backscatter_Mean_532_Par	Float_32	1
Region_2_Merged_Backscatter_Mean_532_Per	Float_32	1
Region_2_Merged_Backscatter_Mean_1064	Float_32	1
Region_1_Merged_Backscatter_Mean_532_Par	Float_32	1
Region_1_Merged_Backscatter_Mean_532_Per	Float_32	1
Region_1_Merged_Backscatter_Mean_1064	Float_32	1
Region_0_Merged_Backscatter_Mean_532_Par	Float_32	1
Region_0_Merged_Backscatter_Mean_532_Per	Float_32	1
Region_0_Merged_Backscatter_Mean_1064	Float_32	1
Gain_Coeff_A_532_Par	Float_32	1
Gain_Coeff_B_532_Par	Float_32	1
Gain_Coeff_C_532_Par	Float_32	1
Gain_Coeff_D_532_Par	Float_32	1
Gain_Coeff_A_532_Per	Float_32	1
Gain_Coeff_B_532_Per	Float_32	1
Gain_Coeff_C_532_Per	Float_32	1
Gain_Coeff_D_532_Per	Float_32	1
Gain_Coeff_A_1064	Float_32	1
Gain_Coeff_B_1064	Float_32	1
Gain_Coeff_C_1064	Float_32	1
Gain_Coeff_D_1064	Float_32	1
Backscatter_532_Parallel	Float_32	583
Backscatter_532_Perpendicular	Float_32	583
Backscatter_1064	Float_32	583

The L0 HDF file will also contains one record of the Lidar_Data_Altitude with data type as Float_32 and has 583 values.

The contents for the Level 1A output file is shown in Table 2. Each file contains same amount data of L0 raw data. The Metadata for these output products is shown in Table 3.

Table 2: LIDAR Level 1A Record

Parameter Name	Data Type	Elem/Rec
Profile_Time (TAI time)	Float_64	1
Profile_UTC_Time (yyyymmdd.ffffff)	Float_64	1

Parameter Name	Data Type	Elem/Rec
Profile_ID	Int_32	1
Day_Night_Flag	Int_8	1
Frame_Number	Int_16	1
Lidar_Mode	Int_16	1
Lidar_Submode	Int_16	1
Lidar_Receiver_Electronics_Status_532_Par	Uint_32	1
Lidar_Receiver_Electronics_Status_532_Per	Uint_32	1
Lidar_Receiver_Electronics_Status_1064	Uint_32	1
Active_Laser_Number	Uint16	1
Laser_Latitude	Float_32	1
Laser_Longitude	Float_32	1
Range_To_Mean_Sea_Level	Float_32	1
Backscatter_Start_Altitude	Float_32	1
Laser_Energy_Monitor_532	Float_32	1
Perpendicular_Amplifier_Gain_532	Float_32	1
Parallel_Amplifier_Gain_532	Float_32	1
Perpendicular_Background_Monitor_532	Float_32	1
Parallel_Background_Monitor_532	Float_32	1
Normalized_Backscatter_532_Parallel	Float_32	583
Normalized_Backscatter_532_Perpendicular	Float_32	583
Region_6_Merged_Shot_RMS_Noise_532_Per	Float_32	1
Region_6_Merged_Shot_RMS_Noise_532_Par	Float_32	1
Laser_Energy_Monitor_1064	Float_32	1
Amplifier_Gain_1064	Float_32	1
Normalized_Backscatter_1064	Float_32	583
Region_6_Merged_Shot_RMS_Noise_1064	Float_32	1
QC_Flag	Uint_32	1
QC_Flag_2	Uint_32	1

Table 3: LIDAR Level 1A Metadata Record

Parameter Name	Data Type	Elem/Rec
Product_ID	Char	80
Date_Time_at_Granule_Start	Char	28
Date_Time_at_Granule_End	Char	28
Date_Time_of_Production	Char	28
Initial_Subsatellite_Latitude	Float_32	1
Initial_Subsatellite_Longitude	Float_32	1
Final_Subsatellite_Latitude	Float_32	1
Final_Subsatellite_Longitude	Float_32	1
Orbit_Number_at_Granule_Start	Uint_32	1
Orbit_Number_at_Granule_End	Uint_32	1
Orbit_Number_Change_Time	Float_64	1
Path_Number_at_Granule_Start	Uint_16	1

Parameter Name	Data Type	Elem/Rec
Path_Number_at_Granule_End	Uint_16	1
Path_Number_Change_Time	Float_64	1
Lidar_L0_Files_Used	Char	240
Number_of_Good_Profiles	Int_32	1
Number_of_Bad_Profiles	Int_32	1
Percent_532-parallel_Bad	Float_32	1
Percent_532-perpendicular_Bad	Float_32	1
Percent_1064_Bad	Float_32	1
Percent_532-parallel_Missing	Float_32	1
Percent_532-perpendicular_Missing	Float_32	1
Percent_1064_Missing	Float_32	1
Lidar_Data_Altitudes	Float_32	583

Section 5 – Benefits, assumptions, risks/issues

The benefits for generation the L0 and L1A file are these files can be generated immediately after the L0 binary files arrive because it does not require any dynamic input file. To generate the L0 HDF files, users can easily to access the L0 data and verify the quality of the data without manipulating the binary L0 data files. Since the L1A contains all the three channels data, only one input file is required (instead of 3 files). The L1A files contain only the required data for downstream processing.

Conclusion

The design of the LIDAR L0 HDF file and L1A file generating PGE can be processed the L0 data immediately after the L0 binary arrive. The users can easier to access the L0 data and study the quality of the L0 data. Since all three channels data are combined into one L1A file, it is less input files required for the downstream processing.

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