

任務定義審查說明

Department of Space Science and Engineering
National Central University

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Wei-Rong Huang

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The Application was used when we prepared the PEARL-1C MDR/SDR.

04

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The Books and Data about Making the CubeSat.

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Summary



01

About MDR

What is the MDR?

1. Phased Project Planning
2. The Definition of NASA

Phased Project Planning

- MDR and SDR is in Phase A.
- (HeptaSat page 19)
- **Phase A: Concept and Technology Development.**

Phase A

Mission definition

System definition

Concept design

Phase B

Bread Board Model

Basic design

Phase C

Engineering Model

Detailed design

Phase D

Flight Model

Phase E

Launch

TABLE 3.0-1 SE Product Maturity from NPR 7123.1

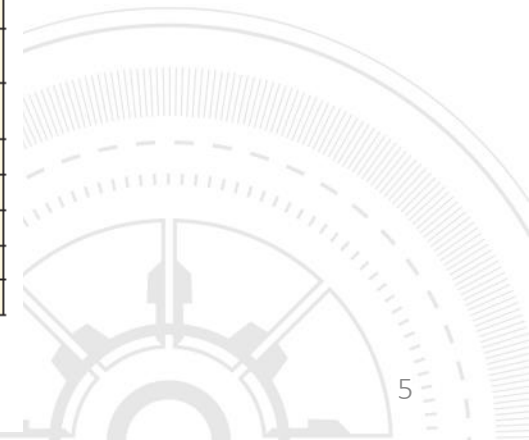
		Formulation			Implementation						
Products	Uncoupled/ Loosely Coupled	KDP 0		KDP I	Periodic KDPs						
	Tightly Coupled Programs	KDP 0			KDP I	KDP II		KDP III		Periodic KDPs	
	Projects and Single Project Programs	Pre- Phase A	Phase A		Phase B	Phase C		Phase D		Phase E	Phase F
		KDP A	KDP B		KDP C	KDP D		KDP E		KDP F	
	MCR	SRR	MDR/SDR	PDR	CDR	SIR	ORR	FRR	DR	DRR	
	Stakeholder identification and	**Baseline	Update	Update	Update						
	Concept definition	**Baseline	Update	Update	Update	Update					
	Measure of effectiveness definition	**Approve									
	Cost and schedule for technical	Initial	Update	Update		Update	Update	Update	Update	Update	Update
	SEMP ¹	Preliminary	**Baseline	**Baseline	Update	Update	Update				
	Requirements	Preliminary	**Baseline	Update	Update	Update					
	Technical Performance Measures definition			**Approve							
	Architecture definition			**Baseline							
	Allocation of requirements to next lower level			**Baseline							
	Required leading indicator trends			**Initial	Update	Update	Update				
	Design solution definition			Preliminary	**Preliminary	**Baseline	Update	Update			
	Interface definition(s)			Preliminary	Baseline	Update	Update				
	Implementation plans (Make/ code, buy, reuse)			Preliminary	Baseline	Update					
	Integration plans			Preliminary	Baseline	Update	**Update				
	Verification and validation plans	Approach		Preliminary	Baseline	Update	Update				
	Verification and validation results						**Initial	**Preliminary	**Baseline		
	Transportation criteria and instructions					Initial	Final	Update			
	Operations plans				Baseline	Update	Update	**Update			
	Operational procedures					Preliminary	Baseline	**Update	Update		
	Certification (flight/use)							Preliminary	**Final		
	Decommissioning plans				Preliminary	Preliminary	Preliminary	**Baseline	Update	**Update	
	Disposal plans				Preliminary	Preliminary	Preliminary	**Baseline	Update	Update	**Update

** Item is a required product for that review

1 SEMP is baselined at SRR for projects, tightly coupled programs and single-project programs, and at MDR/SDR for uncoupled, and loosely coupled programs.



- 任務概念成形
- 衛星設計、執行計畫雛形





02

Example – PEARL-1C

The MDR/SDR of PEARL-1C.

1. Agenda
2. Introduction
3. Mission
4. Schedule/Timeline
5. Division of Work
6. Requirement
7. Subsystem、Payload
8. Budget
9. Mode
10. Mass Budget
11. Power Budget
12. Simulations
13. Feedback

The Outline of PEARL-1C MDR

- Agenda
- Introduction
- Mission
- Schedule/Timeline
- Division of Work
- Requirement
- Subsystem 、 Payload
- Budget
- Mode
- Mass Budget
- Power Budget
- Simulations
- Feedback

Agenda

- MDR報告議程。
- 會前練習。

Time	Content	Speaker
14:00~14:15 (15)	Mission	Name
14:15~14:30 (15)	C&DH	Name
14:30~14:45 (15)	EPS	Name
14:45~15:00 (15)	ADCS	Name
15:00~15:10 (15)	COMM	Name
15:15~15:30 (15)	STR	Name
15:30~15:45 (15)	Payload	Name

PEARL-1C (CubeSat Name)

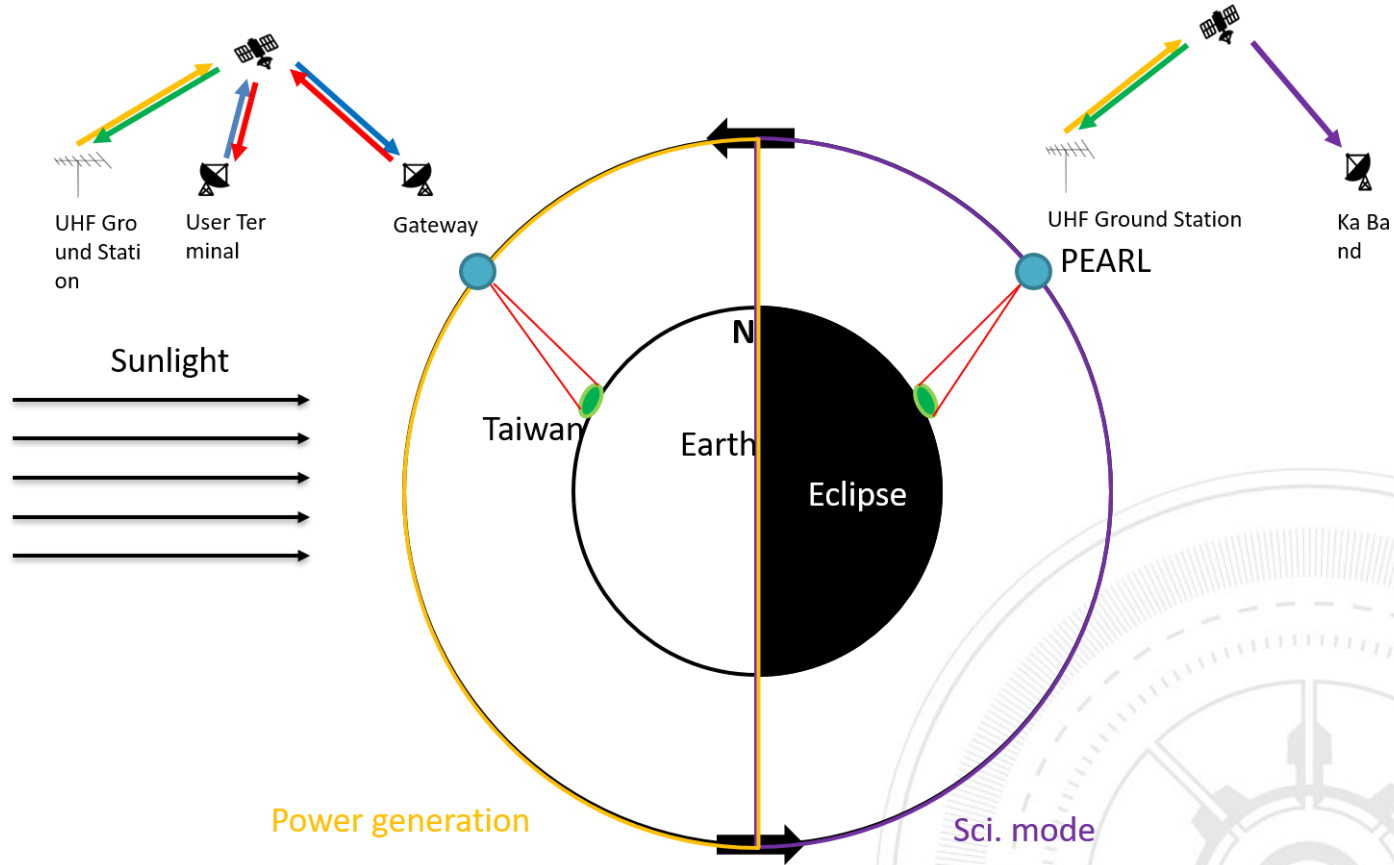


- Propagation Experiment using kurz-Above-band Radio in Low earth orbit
- 衛星名稱
- Dimension: 100 mm x 226.3 mm x 366 mm (6U).
- 衛星尺寸
- Mass: 10~12 kg.
- 重量
- Payloads: **Ka band communication payload** for ground station testing and **Compact Ionospheric Probe (CIP)**.
- 主要任務/酬載
- Orbit: 500-600 km and SSO(Sun-synchronous orbit) for cheaper launch cost.
- 軌道
- Time: **(TBD)**
- 任務執行時間
- Local time: **(TBD)**
- (SSO地方時間)



Mission

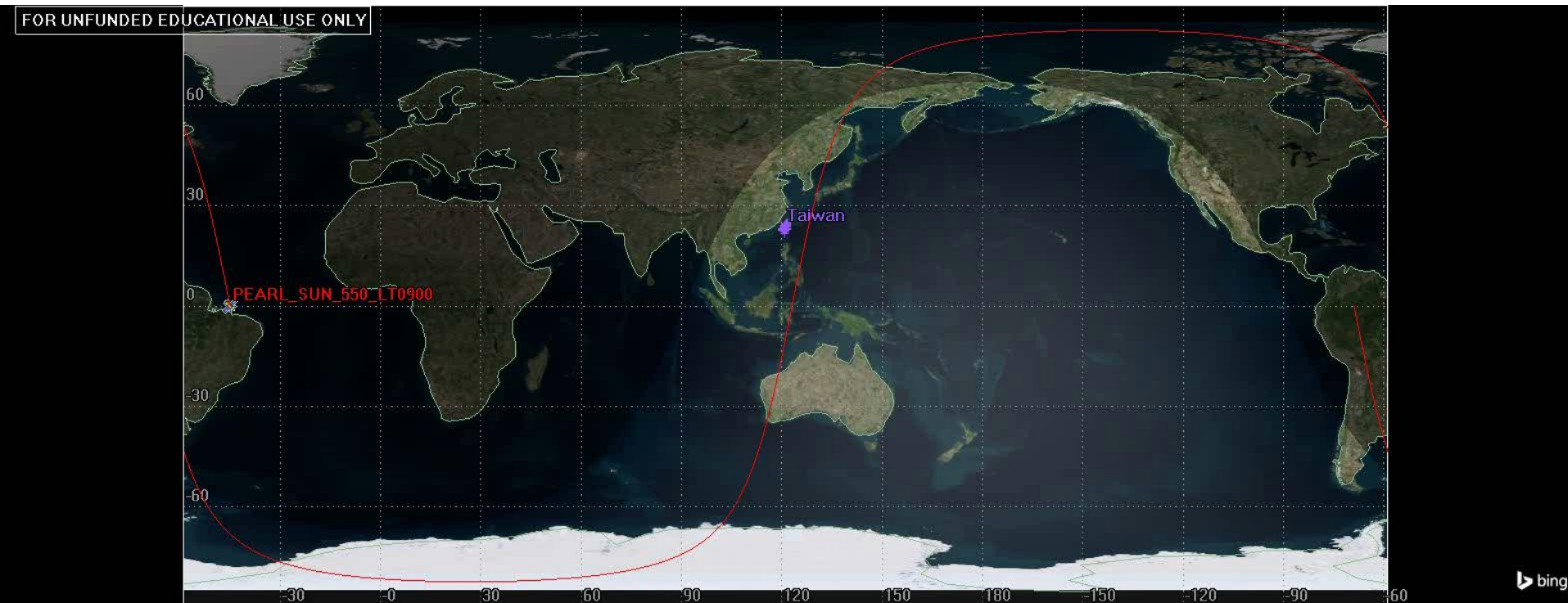
- 任務敘述與圖示。
- 任務目標與運作方式。



Mission (Cont.)

- 展示影片 (2D/3D) 。 (先有任務構想)
- 工具 : STK

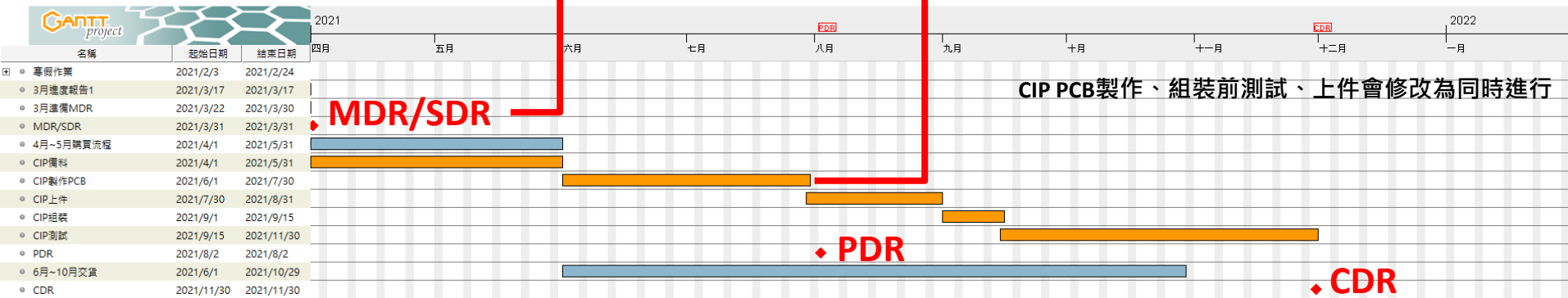
<https://drive.google.com/file/d/1NE8KKAKmNsa0FpPYwj2c7Xi2RY1tGX30/view?usp=sharing>



Schedule /Timeline

- 任務時程規劃
- Example 1

2021



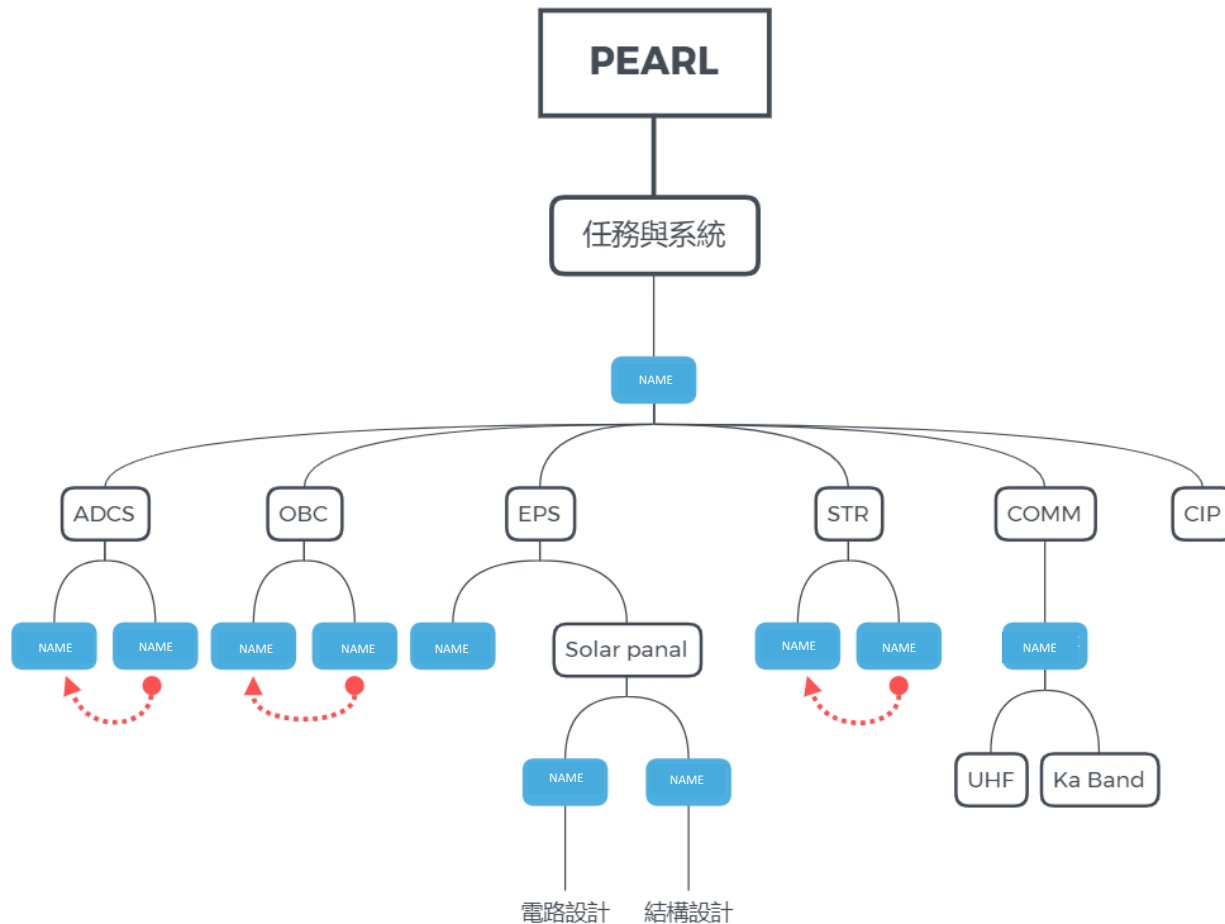
- Example 2

2022



Division of Work

- 分工內容。
- 就任務、人數、人員不同，有不同的規劃。



Requirement

- Level 0: Mission Goals and Objectives
- 等級0：任務目標 → Main
- Level 1: Top Level Requirements
- 等級1：最高任務需求 → 為了達到任務目標而要做的
- Level 2: System Requirements
- 等級2：系統需求 → 為了達到最高任務需求而衛星該有的
- Level 3: Subsystem Requirements
- 等級3：次系統需求 → 為了達到系統需求而次系統應該要有的
- Level 4: Component Requirements
- 等級4：元件需求 → 為了達到次系統需求而元件應有的，獲應有的元件

Requirement (Cont.)

- Main: PEARL上搭載通訊酬載，驗證衛星與地面站使用。
- L0: 驗證通訊酬載，衛星與地面站能夠傳接收科學資料與 beacon。
- L1: PEARL要能夠以Ka頻段下傳科學資料。
- L2: PEARL在不同模式皆能穩定供電。
PEARL的各次系統皆能夠在太空環境的溫度下正常運作。
- L3: 通訊酬載要能對所要傳遞的訊號進行編碼、調變、升頻。
- L4: TBD

Requirement (Cont.)

- 主要要有「敘述」。
- 其他因應任務需求。

PEARL-1

需求與驗證列表

任務敘述 PEARL上搭載通訊酬載，驗證衛星與地面站使用。

Level 0: Mission Goals and Objectives
等級0：任務目標

Ref	Description	Source(s)	Verific ation	Verific ation	Verific ation	Applica ble	Require ment	Comment	Flow Up?	Flow Down?	Flow Across?
0. REQ. S CI. 1	驗證低地球軌道立方衛星Ka頻段通訊之運作。										
0. REQ. S CI. 2	To measure planetary scale waves and structures in the ionosphere, and quantify their variability and contribution to ionospheric										
0. REQ. S CI. 3	To measure the distribution, occurrence rate, and structure of ionospheric irregularities and Travelling Ionospheric Disturbances (TIDs).										
0. REQ. S CI. 4	To infer the electric fields driving horizontal plasma drift, and their relation to the ionospheric F region wind dynamo.										

Requirement (Cont.)

- 建議任何雲端共用，要有版本管理頁面。

PEARL_Mode_Requirement_v6.xlsx - Excel

國立中央大學
太空科學與工程學系

PEARL

版本管理			分工
版本號	日期	內容	ADCS
1.00	2020-10-19	建檔	C&DH
1.01	2020-10-27	新增CDH需求	COMM
1.02	2020-10-27	新增STR需求	EPS
1.03	2020-10-28	新增TCS需求	STR
1.04	2020-10-28	新增COMM需求	
1.05	2020-10-29	新增L0需求、EPS需求、與P/L欄位	
1.06	2020-11-06	補齊ADCS需求, 部分系統需求	
1.07	2020-11-08	新增L1、L2需求	
2.00	2020-11-12	彙整、新增STR FR	
3.00	2020-11-23	Mode 修改	
3.01	2021-02-04	Mode 修改、暫時刪減STT模式	
3.02	2021-03-17	ADCS需求修改	
4.00	2021-03-24	針對PEARL兩顆衛星任務作修正以及MDR	
4.01	2021-03-24	STR修改	
4.02	2021-03-25	EPS需求修改	
4.03	2021-03-25	新增CIP需求	
4.04	2021-03-26	修改任務目標與COMM需求、新增通訊酬載需求	

重要
估計
待定

版本管理 | Mode | PEARL-1 Requirement | PEARL-2 Requirement | IDEASSat副本

Example

L3: OBC Requirement - Functional Requirements (FR)

Description
C&DH 要收集並儲存各個次系統的Housekeeping data 。
C&DH要擁有一個主要的衛星時鐘 。
C&DH 要維持電力平衡 。
C&DH至少要儲存3個月的Housekeeping data 。（TBD）
C&DH要能追蹤Power Peak 。
C&DH要確認彈射裝置(天線和太陽能板)的情況，必要時再次進行彈射 。
C&DH要持續燒釣魚線，直到接收到地面的指令 。
C&DH要能下指令給ADCS並從ADCS接收資料 。
C&DH要能下指令給UHF並從UHF接收資料 。（TBD）
C&DH要能下指令給通訊酬載 。（TBD）
C&DH在一天之內沒有接收到地面上傳資料，要自主重新開機 。
C&DH要有外部接頭供地面測試使用 。
C&DH要能處理來自Ka-band的User Terminal和Gateway的上下傳資料

Example

L3: OBC Requirement - Performance Requirements (PR)

Description

在離開彈射筒後要等待30分鐘才進入部屬模式。

Switch開的時候，時間要從0開始。

FSW要能控制各個次系統。

FSW要能偵測電量多寡，適時調配。

FSW要能判斷地面站接收範圍，自動調整姿態

Subsystems、Payload

- EnduroSat → 公司名或研發單位
 - 6U Structure
 - EPS II + battery pack
 - 6U Deployable solar array
 - 3U Deployable solar array RBF
 - On-board Computer + Software Development Kit (SDK)
 - GNSS + antenna
 - CubeSpace ADCS (3-axis) 6U high
 - UHF transceiver
 - UHF 2U antenna (bottom) + [UHF 2U antenna + solar panel (top)]
 - Ka-band Tx Antenna + Ka-band Rx Antenna
 - UHF Ground Station equipment
- 項目

- Arralis (TBD)
 - Ka band transceiver
- SPL
 - Compact Ionospheric Probe (CIP)

Budget

- 預算規劃。
- 任務可行性。
- 建議加上採買元件時程（結合前面Schedule /Timeline也行）

購買項目	品名	價錢	貨幣	匯率	數量	購買網址	Datasheet
PEARL 預算							
ADCS							
ASM	ADXL345 三軸加速度計		NTD		4	https://reurl.cc/KjlgXj	https://reurl.cc/KjlgXj
	HMC5883L三軸電子羅盤		NTD		4	https://reurl.cc/KjlgXj	https://reurl.cc/KjlgXj
	L3G4200D三軸陀螺儀		NTD		4	https://reurl.cc/5qdn0G	https://reurl.cc/5qdn0G
GPS	Pmod-GPS		NTD		3	https://reurl.cc/D615jQ	https://reurl.cc/D615jQ
Camera					1		
Sun Sensor	Dual Solar Sensor		NTD		3	https://reurl.cc/8nb3do	https://reurl.cc/8nb3do
Reaction wheel					1		
Magnetorquer					1		
PCB	洗板上件估計一片		NTD		5		
FPGA							
C&DH							
SOM	smart Fusion2 SOM		USD		30	https://store.emcraft.com/ShoppingCart.asp	https://www.
	smart Fusion2 SOM start kit		USD		2	https://store.emcraft.com/ShoppingCart.asp	
介面PCB	洗板上件估計一片		NTD		5		
micro SD			NTD		5		
SD slot			NTD		10		
Component	DF40HC(4.0)-80DS-0.4V(51)		NTD		10	https://www.mouser.tw/ProductDetail/Hirose-Connector/DF40HC40-80DS-04V51?qs=%2	
COMM							
UHF	SpaceQuest TRX-U		USD		2	https://www.spacequest.com/components/7	https://i.s
	UHF Linear Monopole Antenna		USD		2	https://www.spacequest.com/components/3	https://i.s

Mode

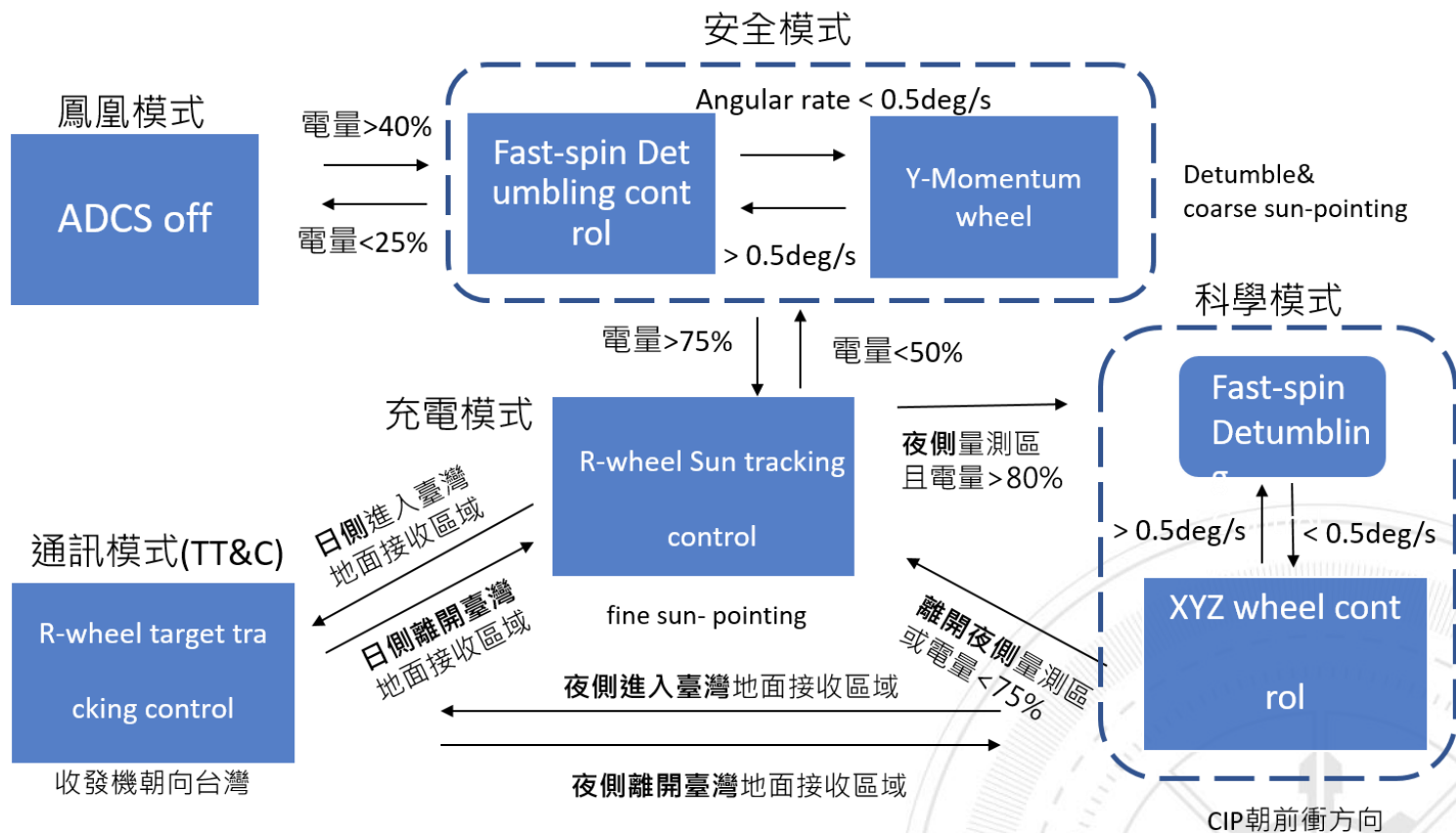
- 模式切換表格。
- 次系統的開啟與關閉。

	儲備電量不足		儲備電量足夠		
	Phoenix	Safe	Charging	Science	TT&C
ADCS	OFF	ON/粗略指向模式 (safe mode/ detumble mode)	ON/精細指向模式 (sun-pointing)	ON/CIP朝前衝方向	ON/收發機指向台灣地面站 (nadir-pointing mode)
C&DH	ON	ON	ON	ON	ON
EPS	ON	ON	ON	ON	ON
UHF(Tx)	BEACON	BEACON	BEACON	BEACON	BEACON (TBD)
UHF(Rx)	ON	ON	ON	ON	ON
CIP	OFF	OFF	OFF	ON	OFF
Ka band	OFF	OFF	OFF	OFF	ON/BEACON

TT&C: Telemetry, Tracking and Command

Mode (Cont.)

- 模式切換Flow chart
- 模式切換條件



Mass Budget

- 估算各次系統重量、衛星重量。
- 確保不會過重。
- Example:

Subsystem	Weight(g)	Num.	Weight(g)
UHF	90	1	90
UHF antenna	85	2(2U)	170
OBC	130	1	130
EPS+Battery	1350	1	1350
6U Solar Array	677	2	1354
3U Solar Array	270	1	270
STR	850	1	850
CIP	433	1	433
ADCS	960	1	960
Total (including 30% margin)			7289.1
For Ka Band and Wire			4710.9

Power Budget

- 估算電力使用。
- 評估任務可行性。
- Example:

Subsystem	V(V)	I(A)	Power(W)
UHF	3.3	0.025	0.0825
UHF (Transmit)	(TBC)	(TBC)	2
Antenna (Max)	5	(TBC)	3.5
UHF	3.3	0.025	0.0825
UHF (Transmit)	(TBC)	(TBC)	2
Antenna (Max)	5	(TBC)	3.5
OBC	(TBC)	(TBC)	0
EPS+Battery	(TBC)	(TBC)	0
6U Solar Array	(TBC)	(TBC)	0
3U Solar Array	(TBC)	(TBC)	0
CIP	12	0.3	3.6
ADCS (Ave.)	(TBC)	(TBC)	0.517
ADCS (Peak)	(TBC)	(TBC)	2.295
Ka Band	(TBC)	(TBC)	(TBC)
Total			17.577

Simulation

- 模擬內容。
- 評估任務可行性，進而規劃如何執行。
- 針對任務做不同模擬。
- **Example:**

Time: 2022.01.01 00:00:00 ~2022.02.01 00:00:00

Altitude: 550 km

LTDN:0900

Elevation angle: 10 deg

	times	Start	End	Period (min)
Min Duration	39	13 Jan 2022 13:46:39. 597	13 Jan 2022 13:47:31.318	0.862
Max Duration	61	21 Jan 2022 01:04:45. 067	21 Jan 2022 01:12:39.803	7.912
Mean Duration				6.154
Total Duration				547.727

Feedback

- 會議記錄：MDR時有人記錄或錄音錄影。
- 問題統整要回覆回條給與會者。

MDR_SDR問題回條_final.pdf - Adobe Acrobat Pro

檔案(F) 編輯(E) 檢視(V) 視窗(W) 說明(H)

開啟 建立 203%

自訂 工具 填寫和簽署 注釋

PEARL
MDR/SDR 回條

問題	回覆
Overview	
<ul style="list-style-type: none">• 在 overview 加上任務目標。	<ul style="list-style-type: none">• 這次只以圖示呈現，未來會增加敘述。
<ul style="list-style-type: none">• 要放 6U 衛星結構示意圖。	<ul style="list-style-type: none">• 未來會補上。
<ul style="list-style-type: none">• Mode：nadir 表示正下方，要是 surface pointing 才是追蹤目標。	<ul style="list-style-type: none">• 在 Overview 填寫錯誤，TT&C 是 surface pointing，ADCS 也以卻認為這個定義。



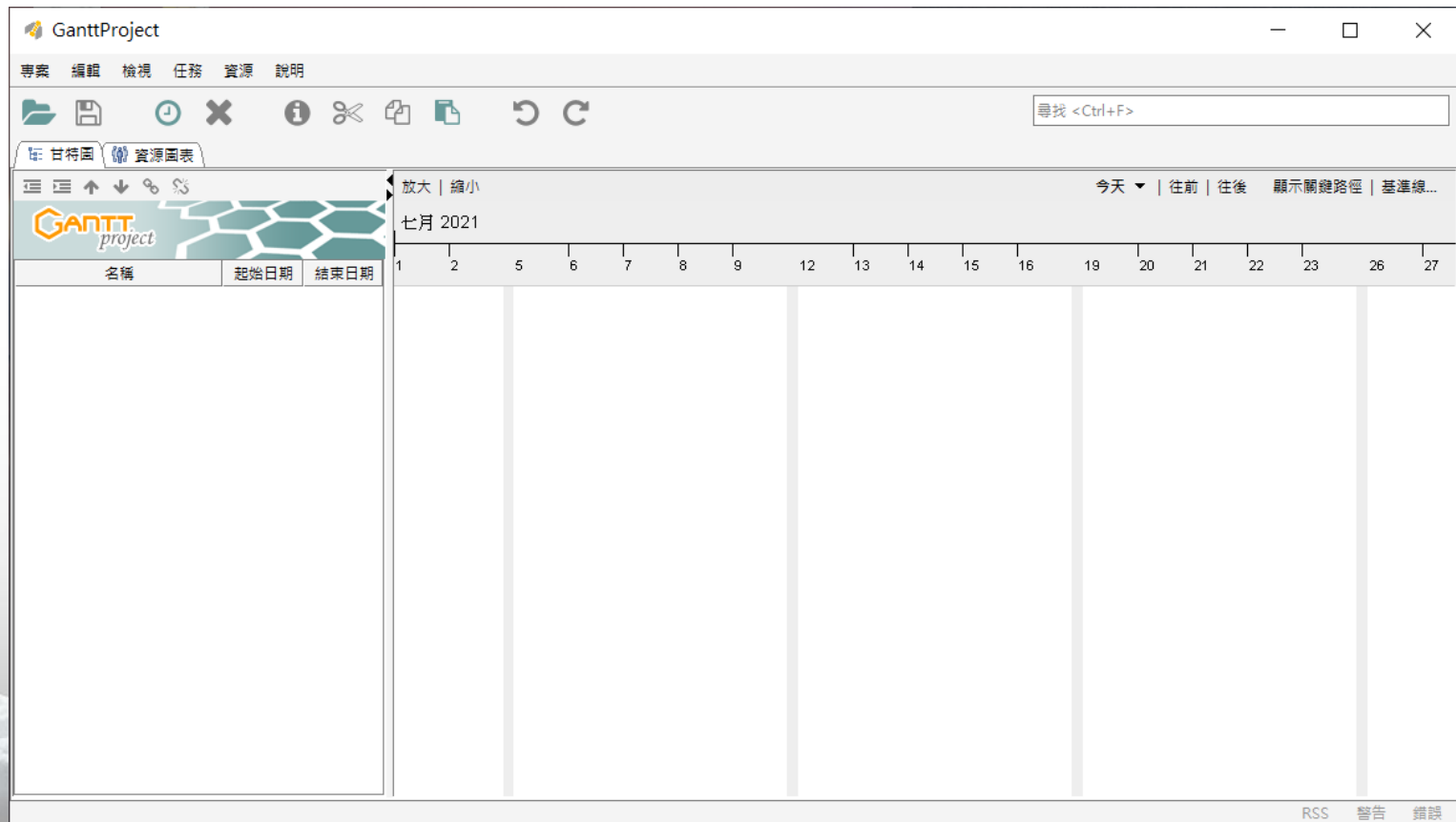
03 Application

The Software was used when we prepared the PEARL-1C MDR/SDR.

1. GanttProject
2. Xmind
3. draw.io

排程用應用程式

- GanttProject
- 甘特圖



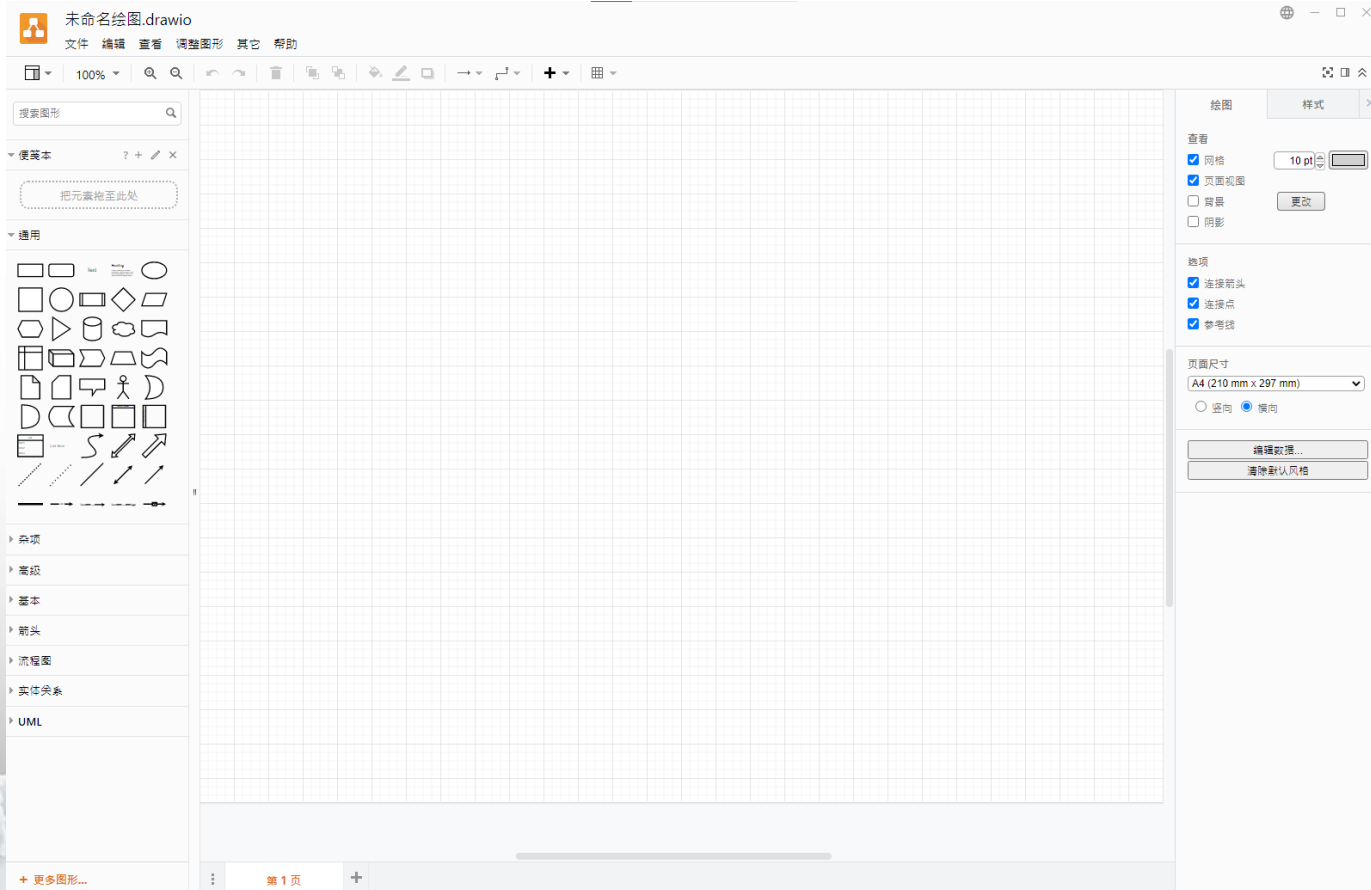
心智圖應用程式

- XMind ZEN (模組較多)。
- XMind 8 Update 8 (自定義較多)。



流程圖應用程式

- draw.io
- 流程圖.....等。





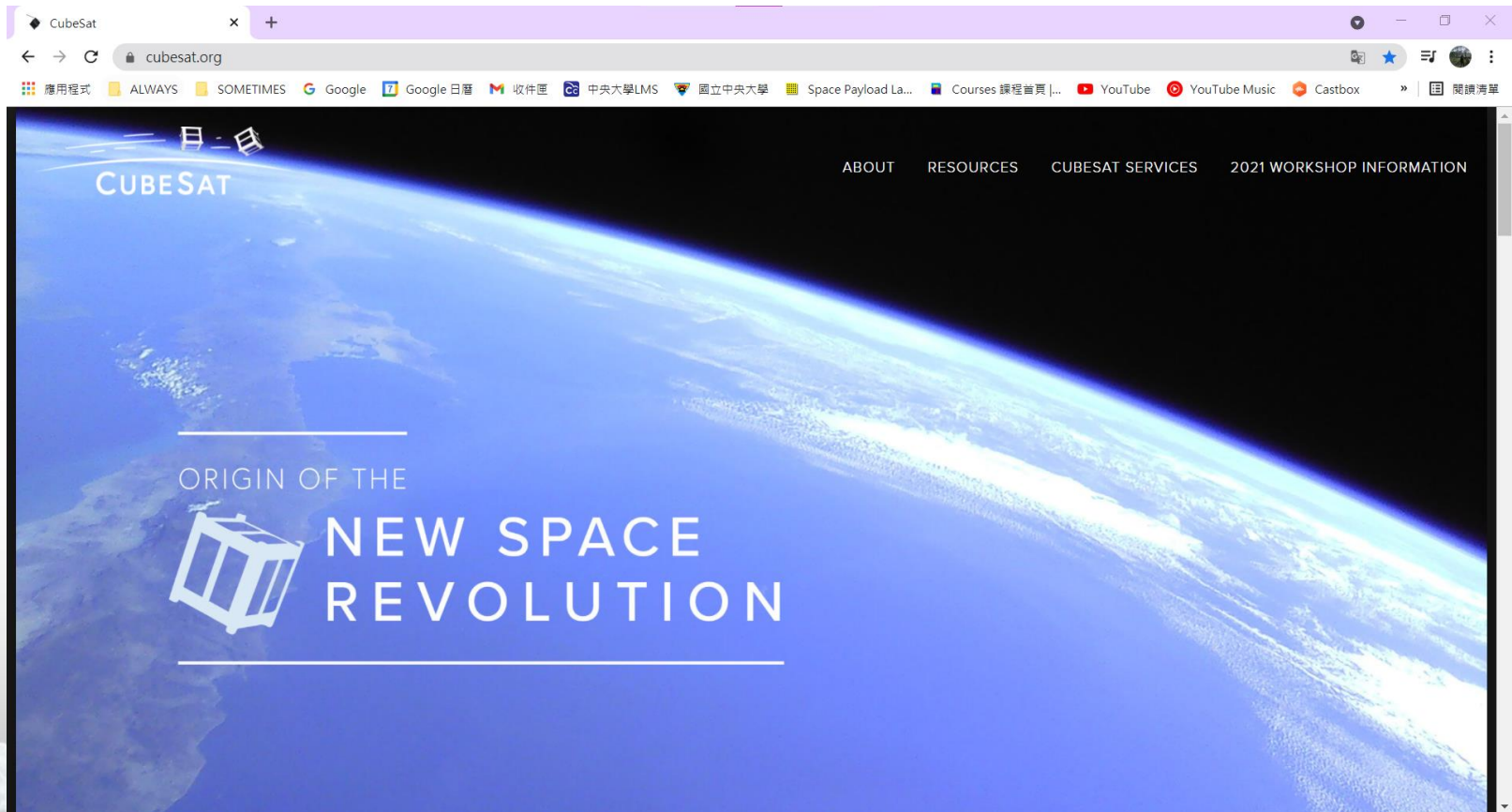
04 Reference

The Books and Data about Making the CubeSat.

1. CubeSat Design Specification
2. CubeSat 101
3. Systems Engineering Handbook

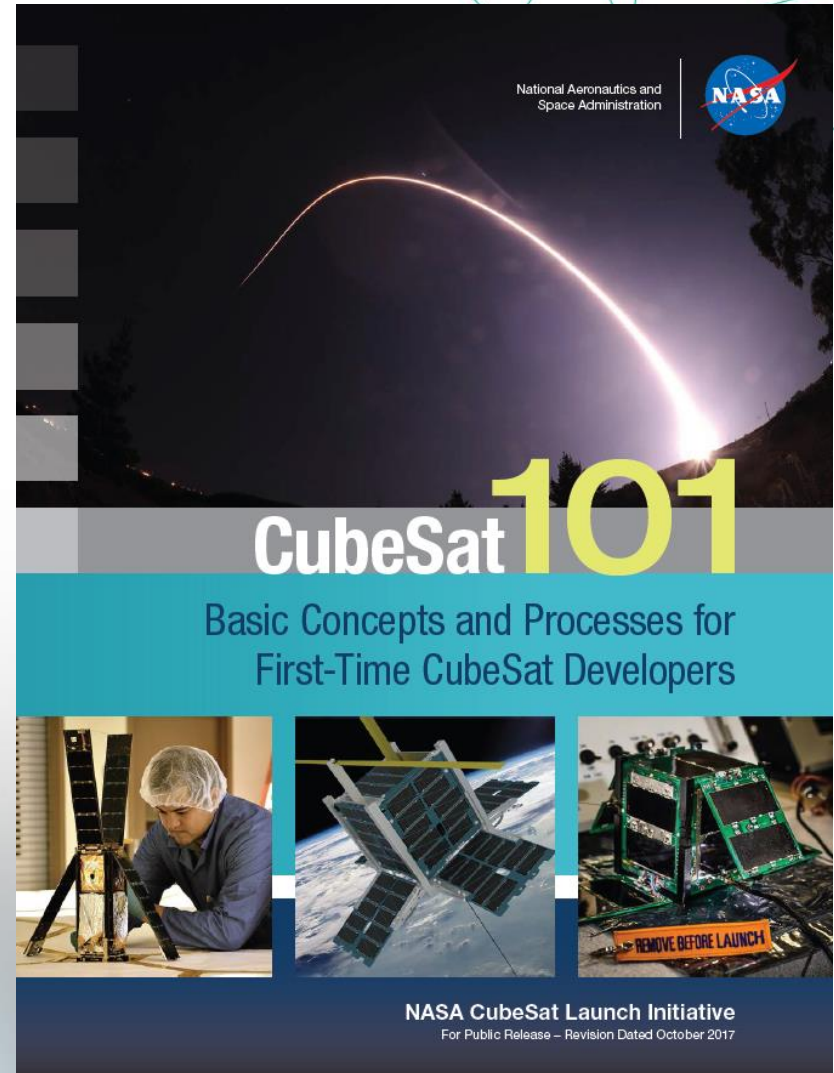
CubeSat Design Specification

- <https://www.cubesat.org/>



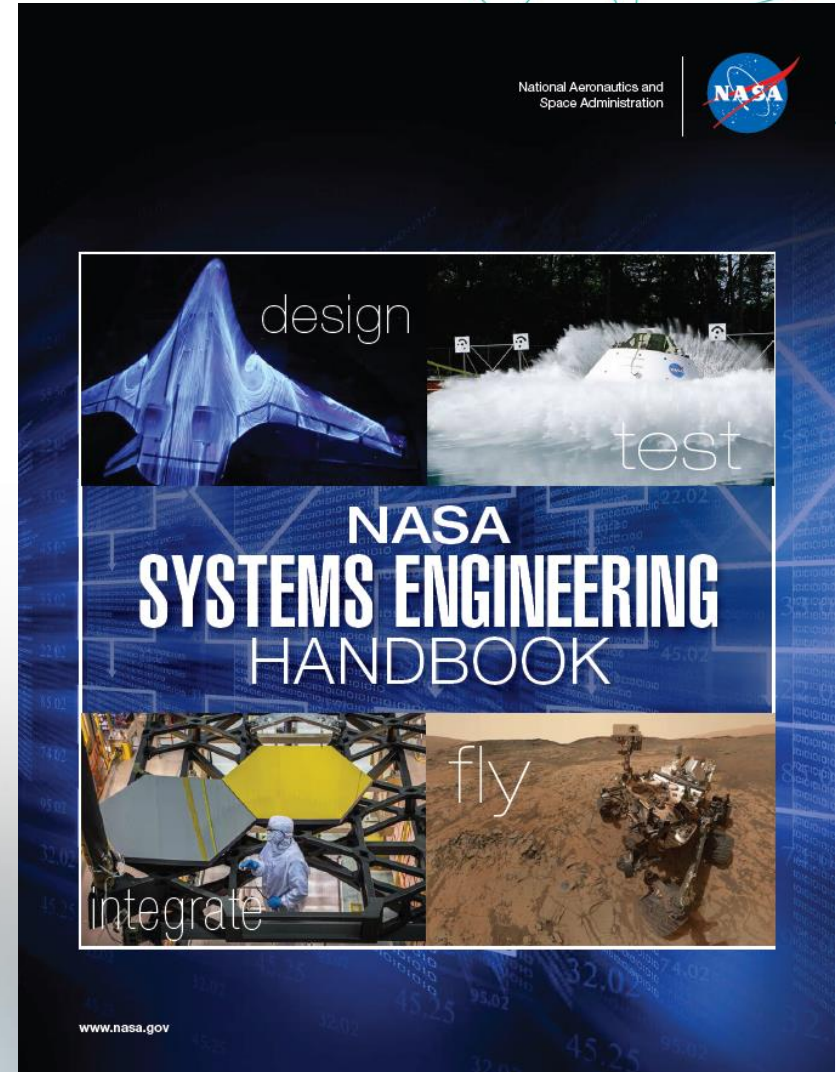
CubeSat 101

- 製作立方衛星的流程。
- 很多美國官方的流程。
- https://www.nasa.gov/sites/default/files/atoms/files/nasa_csli_cubesat_101_508.pdf



Systems Engineering Handbook

- 系統工程。
- <https://www.nasa.gov/connect/ebooks/nasa-systems-engineering-handbook>

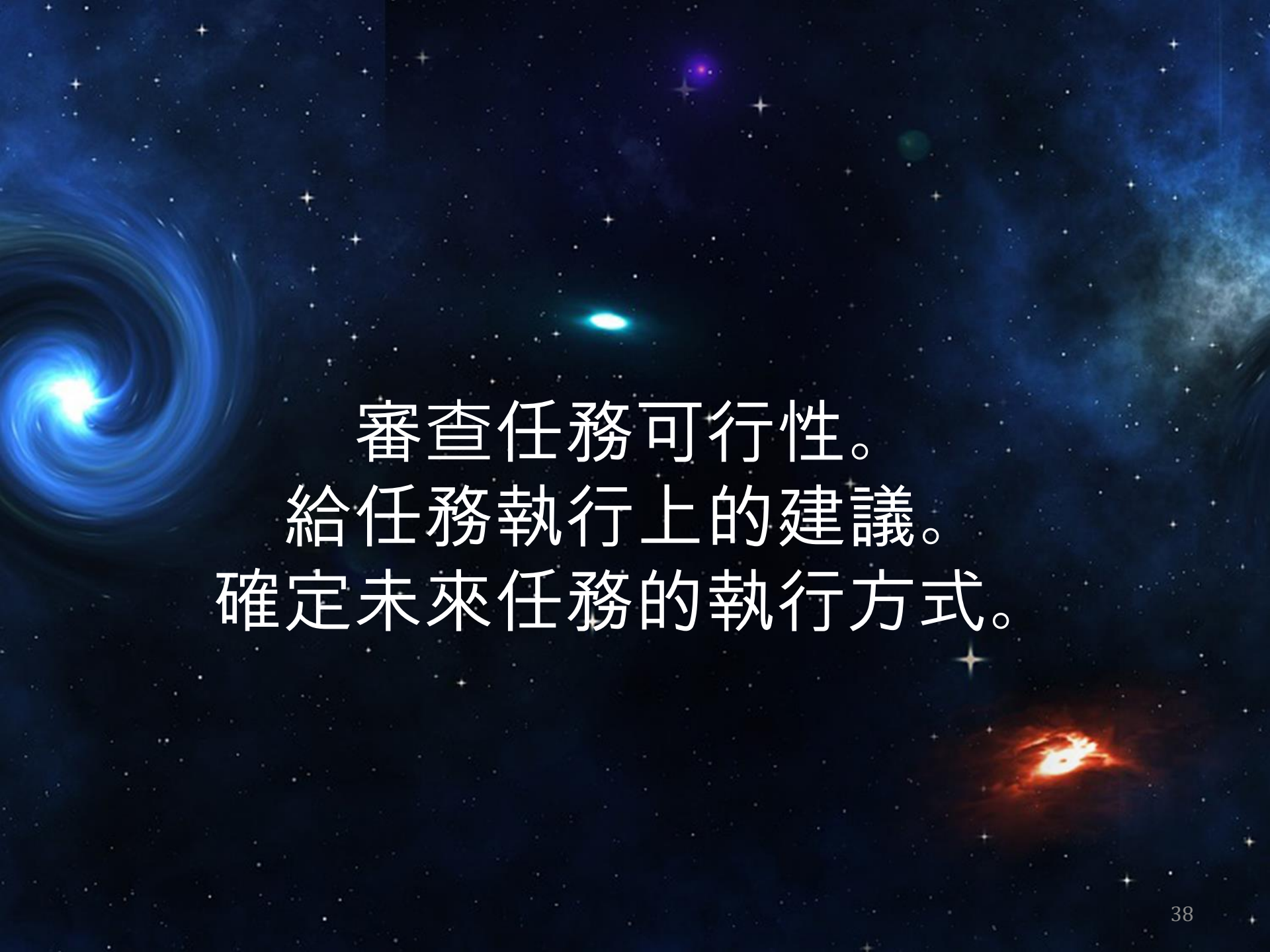




05
Summary



所以MDR大概是...



審查任務可行性。
給任務執行上的建議。
確定未來任務的執行方式。

縮寫表

- To Be Determined (TBD)
- To Be Resolved (TBR)
- To Be Confirmed (TBC)

- Command & Data Handling (C&DH)
- Electronic Power System (EPS)
- Attitude Determination and Control System (ADCS)
- Communication System (COMM)
- Structure (STR)
- Payload (P/L)



THANK YOU