

# 任務定義審查MDR說明

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Jul. 2, 2021  
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What is the MDR?

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The MDR/SDR of PEARL.

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

04

## Reference

The Books and Data about Making the CubeSat.

05

## Summery



# Timeline

- 2021/7/2 (FRI)
- 中午前報名，至少五人一組（最好是同班同學），請填選以下表單 <https://forms.gle/XaUcWJhz8r3vKztY7>。14:00-15:00 任務定義審查說明。
- 2021/7/30 (FRI)
- 14:00-17:00 任務定義審查（Mission Definition Review, MDR）與系統設計審查說明。
- 2021/9/3 (FRI)
- 14:00-17:00 系統設計審查（System Design Review, SD R）。





# 01 About MDR

What is the MDR?

1. Phased Project Planning
2. NASA's Definition

# 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

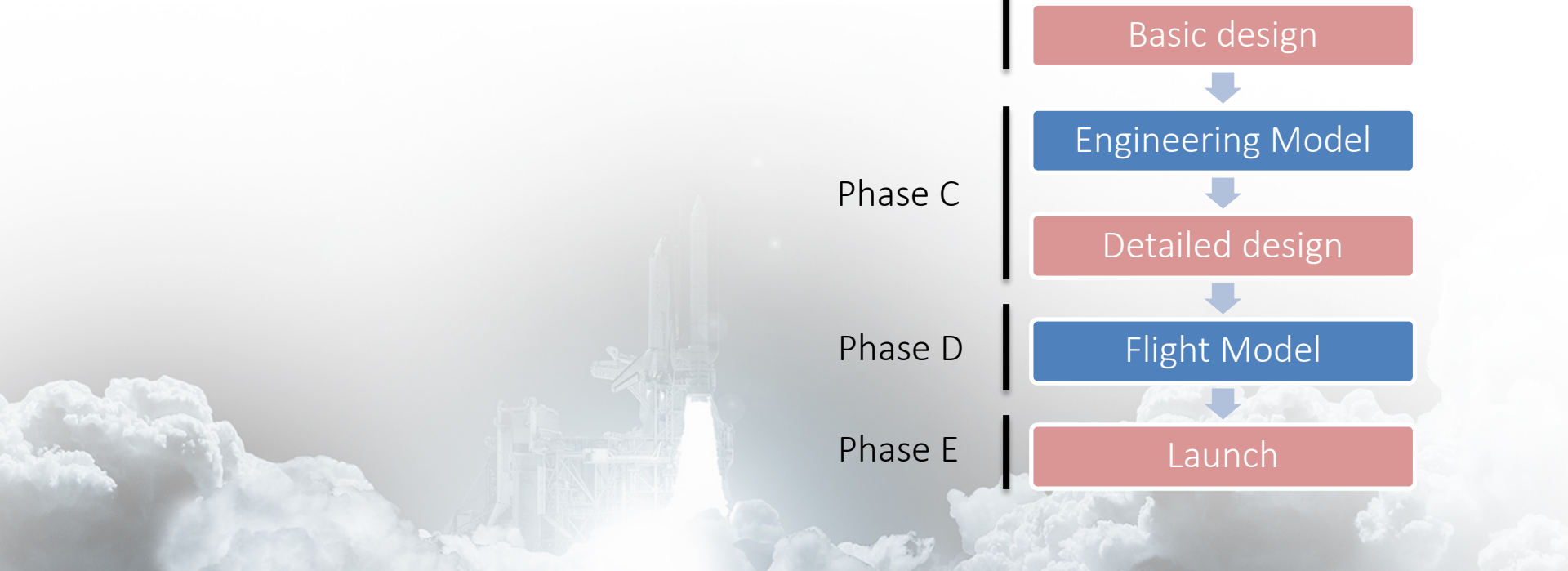


TABLE 3.0-1 SE Product Maturity from NPR 7123.1

		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 <sup>1</sup>	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

<sup>1</sup> 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

The MDR/SDR of PEARL.

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

# Example - PEARL

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





# Agenda

Time	Content	Speaker
14:00~14:15 (15)	<a href="#"><u>Mission</u></a>	黃唯蓉
14:15~14:30 (15)	<a href="#"><u>C&amp;DH</u></a>	洪華廷
14:30~14:45 (15)	<a href="#"><u>EPS</u></a>	楊瑞安
14:45~15:00 (15)	<a href="#"><u>ADCS</u></a>	蔡惠心
15:00~15:10 (10)	<a href="#"><u>COMM-UHF</u></a>	謝宜軒
15:10~15:20 (10)	<a href="#"><u>COMM-Ka Band</u></a>	謝宜軒
15:20~15:35 (15)	<a href="#"><u>STR</u></a>	高譽嘉
15:35~15:45 (10)	<a href="#"><u>Payload-CIP</u></a>	馮佳音

# PEARL

- Propagation Experiment using kurz-Above-band Radio in Low earth orbit
- Dimension: 100 mm x 226.3 mm x 366 mm (6U).
- Mass: 10~12 kg.
- Payloads: **Ka communication payload** for ground station testing and **Compact Ionospheric Probe (CIP)**.
- Orbit: 500-600 km and SSO(Sun-synchronous orbit) for cheaper launch cost.
- Time: **(TBD)**
- Local time: **(TBD)**

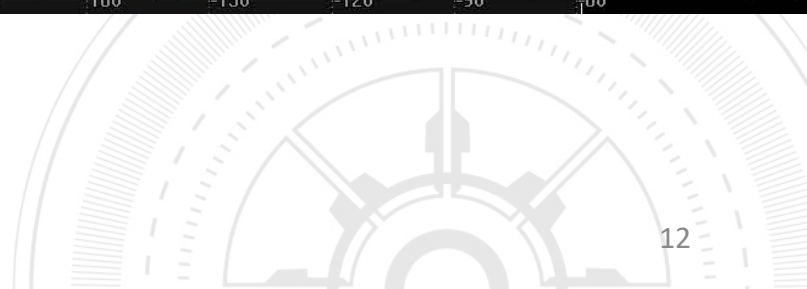
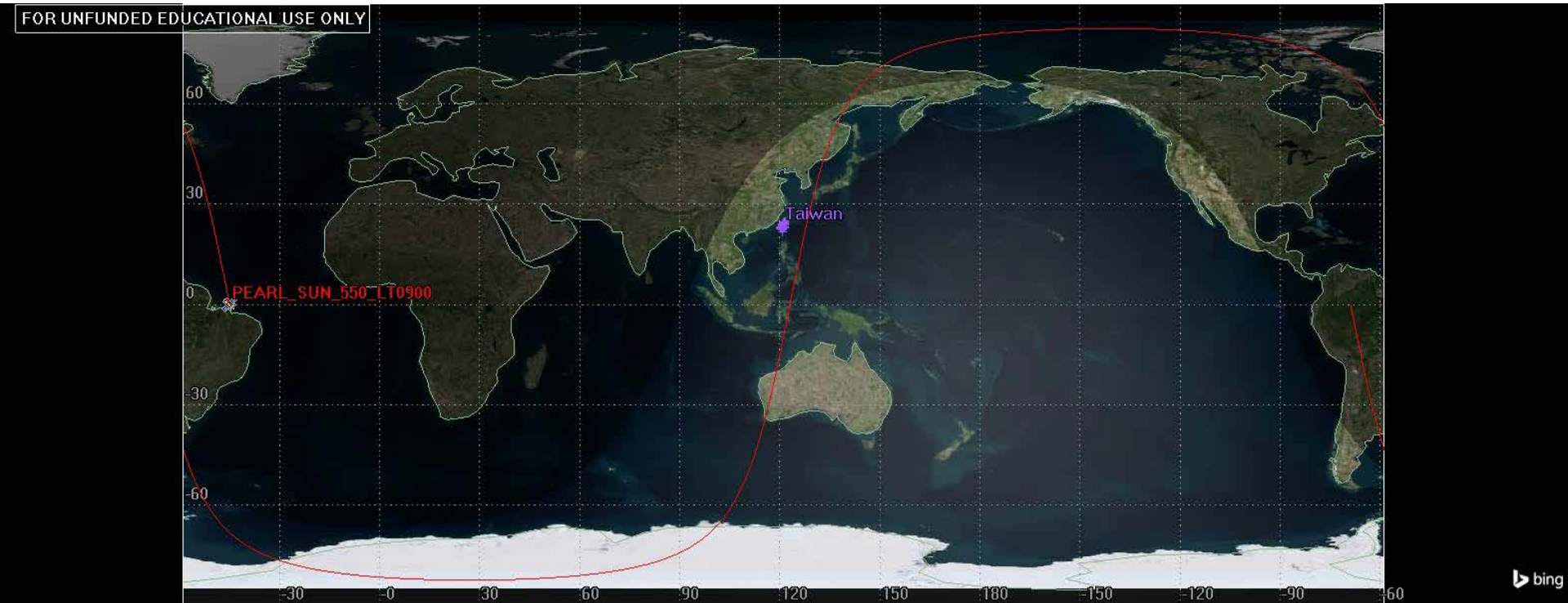




# Mission Simulation 2D Movie



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



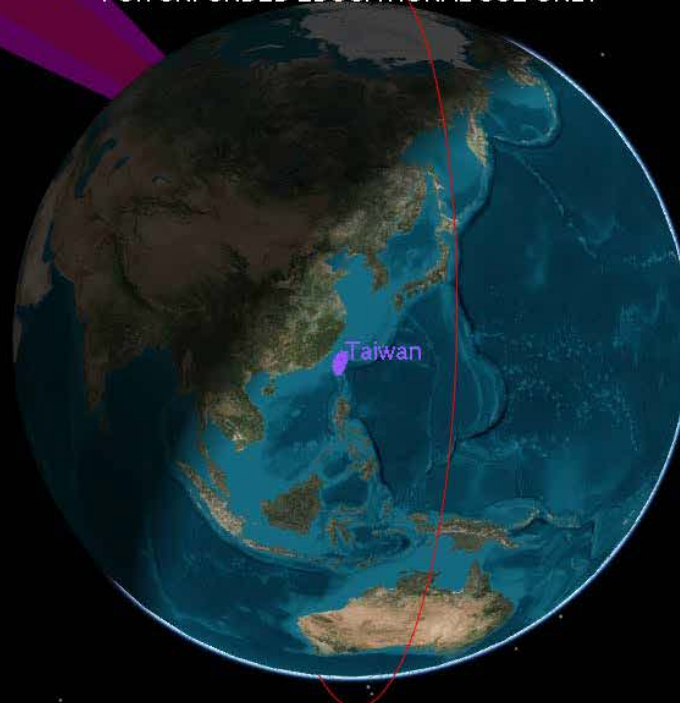


# Mission Simulation 3D Movie



<https://drive.google.com/file/d/1A1INmhHC5Y0mqAE3d6FJa-w3WXzWuSJ3/view?usp=sharing>

FOR UNFUNDED EDUCATIONAL USE ONLY

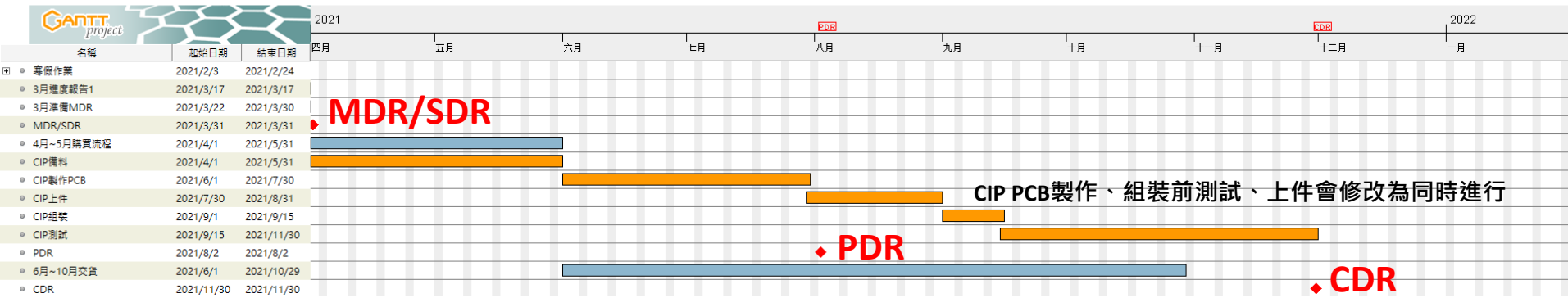


Earth Inertial Axes  
1 Jan 2022 00:00:48.000 Time Step: 48.00 sec

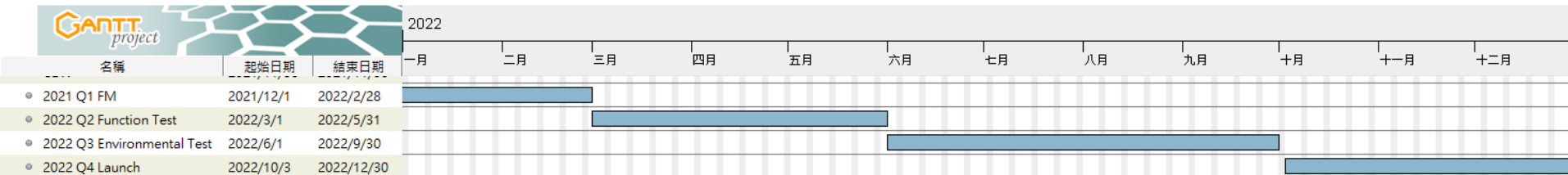


# Schedule

## 2021

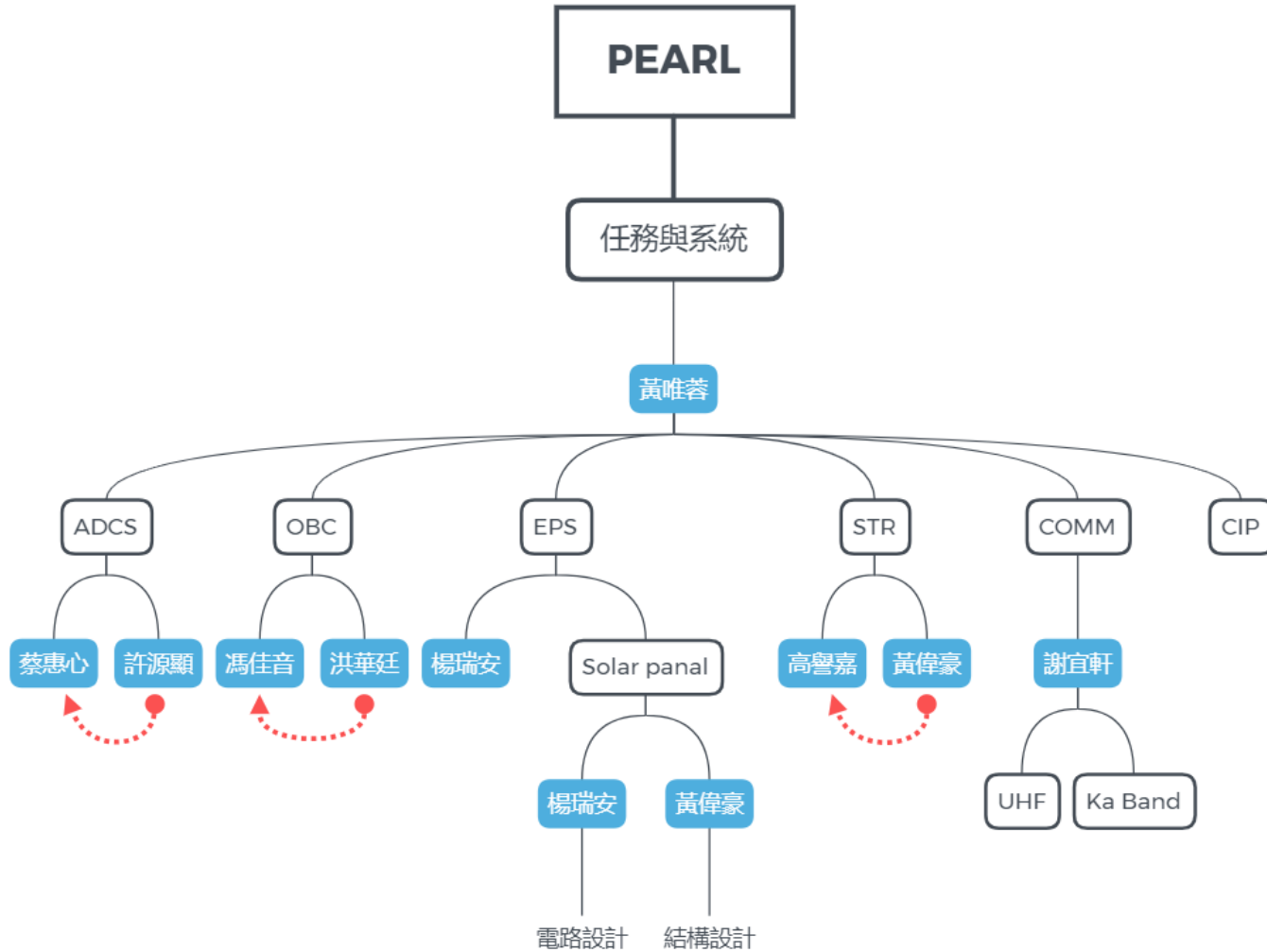


## 2022





# Division of Work



# Budget

PEARL\_budget\_v3.xlsx - Excel

檔案 常用 插入 版面配置 公式 資料 校閱 檢視 說明 告訴我您想做什麼

剪下 複製 貼上 複製格式 剪貼簿 字型 對齊方式 數值 格式 一般 中等 好 壞 已瀏覽過... 計算方式 插入 刪除 格式 儲存格 自動加總 填滿 清除 排序與篩選 尋找與選取 編輯

	A	B	C	D	E	F	G	H	
1	PEARL 預算								
2									
3	購買項目	品名	價錢	貨幣	匯率	數量	購買網址	Datasheet	
4	ADCS								
5	ASM	ADXL345 三軸加速度計	63 NTD			1	4	252 <a href="https://reurl.cc/KjlgYj">https://reurl.cc/KjlgYj</a>	<a href="https://reurl.cc/KjlgYj">https://reurl.cc/KjlgYj</a>
6		HMC5883L三軸電子羅盤	121 NTD			1	4	484 <a href="https://reurl.cc/KjlgYj">https://reurl.cc/KjlgYj</a>	<a href="https://reurl.cc/KjlgYj">https://reurl.cc/KjlgYj</a>
7		L3G4200D三軸陀螺儀	105 NTD			1	4	420 <a href="https://reurl.cc/5qdnOG">https://reurl.cc/5qdnOG</a>	<a href="https://reurl.cc/5qdnOG">https://reurl.cc/5qdnOG</a>
8	GPS	Pmod-GPS	1291.68 NTD			1	3	3875.04 <a href="https://reurl.cc/D615iQ">https://reurl.cc/D615iQ</a>	<a href="https://reurl.cc/D615iQ">https://reurl.cc/D615iQ</a>
9	Camera					1		0	
10	Sun Sensor	Dual Solar Sensor	682.82 NTD			1	3	2048.46 <a href="https://reurl.cc/8nb3do">https://reurl.cc/8nb3do</a>	<a href="https://reurl.cc/8nb3do">https://reurl.cc/8nb3do</a>
11	Reaction wheel					1		0	
12	Magnetorquer					1		0	
13	PCB	洗板上件估計一片	30000 NTD			1	5	150000	
14	FPGA							0	
15								0	
16	C&DI								
17	SOM	smart Fusion2 SOM	165 USD			30	3	14850 <a href="https://store.emcraft.com/ShoppingCart.asp">https://store.emcraft.com/ShoppingCart.asp</a>	<a href="https://www.">https://www.</a>
18		smart Fusion2 SOM start kit	219 USD			30	2	13140 <a href="https://store.emcraft.com/ShoppingCart.asp">https://store.emcraft.com/ShoppingCart.asp</a>	
19	介面PCB	洗板上件估計一片	30000 NTD			1	5	150000	
20	micro SD		1000 NTD			1	5	5000	
21	SD slot		150 NTD			1	10	1500	
22	Component	DF40HC(4.0)-80DS-0.4V(51)	64.6 NTD			1	10	646 <a href="https://www.mouser.tw/ProductDetail/Ilrose_Connector/DF40HC40-80DS-04V51?qs=%2">https://www.mouser.tw/ProductDetail/Ilrose_Connector/DF40HC40-80DS-04V51?qs=%2</a>	
23									
24	COMM								
25	UIF	SpaceQuest TRX-U	18000 USD			30	2	1080000 <a href="https://www.spacequest.com/components/7">https://www.spacequest.com/components/7</a>	<a href="https://i.s">https://i.s</a>
26		UIF Linear Monopole Antenna	1000 USD			30	2	60000 <a href="https://www.spacequest.com/components/3">https://www.spacequest.com/components/3</a>	<a href="https://i.s">https://i.s</a>

版本管理 預算 實際花費

100%

# Requirement

- Level 0: Mission Goals and Objectives
- 等級0：任務目標
- Level 1: Top Level Requirements
- 等級1：最高任務需求
- Level 2: System Requirements
- 等級2：系統需求
- Level 3: Subsystem Requirements
- 等級3：次系統需求
- Level 4: Component Requirements
- 等級4：元件需求





# Requirement (Cont.)

PEARL\_Mode\_Requirement\_v6.xlsx - Excel

檔案 常用 插入 版面配置 公式 資料 校閱 檢視 說明 告訴我您想做什麼

剪下 複製 貼上 剪貼簿 格式 儲存格 編輯

C154 在進入軌道完成部署之後，應進入安全模式。

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

科學目標 Science	Ref	Description	Source(s)	Verification	Verification	Verification	Applicable	Requirement	Comments	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.										

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

就緒 100%

# Requirement (Cont.)

PEARL\_Mode\_Requirement\_v6.xlsx - Excel

檔案 常用 插入 版面配置 公式 資料 校閱 檢視 說明 告訴我您想做什麼 登入 公用

剪下 複製 貼上 複製格式 剪貼簿 字型 對齊方式 數值 樣式 儲存格 編輯

A1

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

版本管理 | Mode | PEARL-1 Requirement | PEARL-2 Requirement | IDEASat範本

就緒 100%

# 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。



# OBC Requirement - Functional Requirements (FR) (Cont.)

Description

C&DH要能處理來自Ka-band的User Terminal和Gateway的上下傳資料

# 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

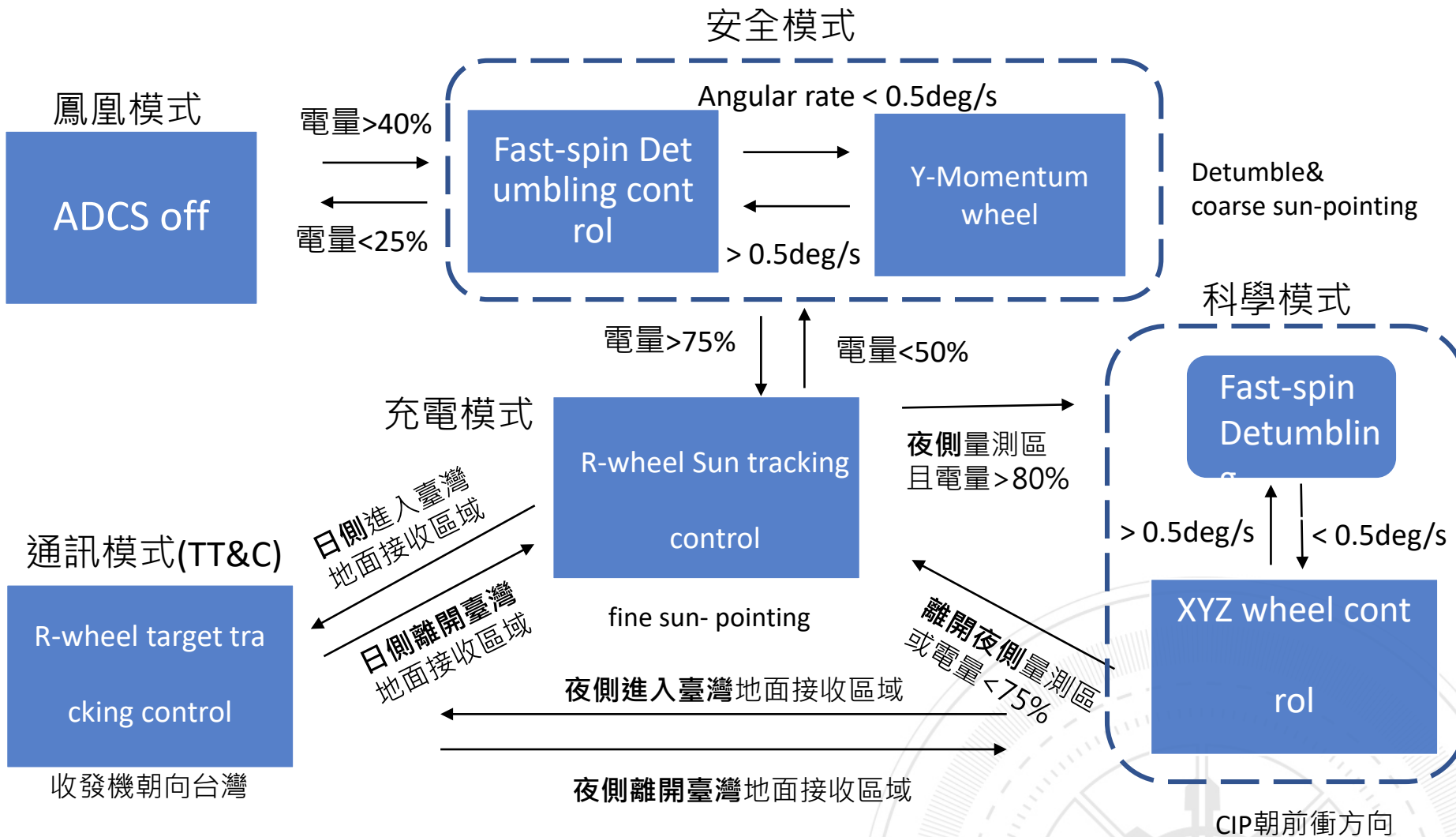
# Mode (TBD)

	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



# Flow chart (TBD)



# Subsystems

- EnduroSat

- 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

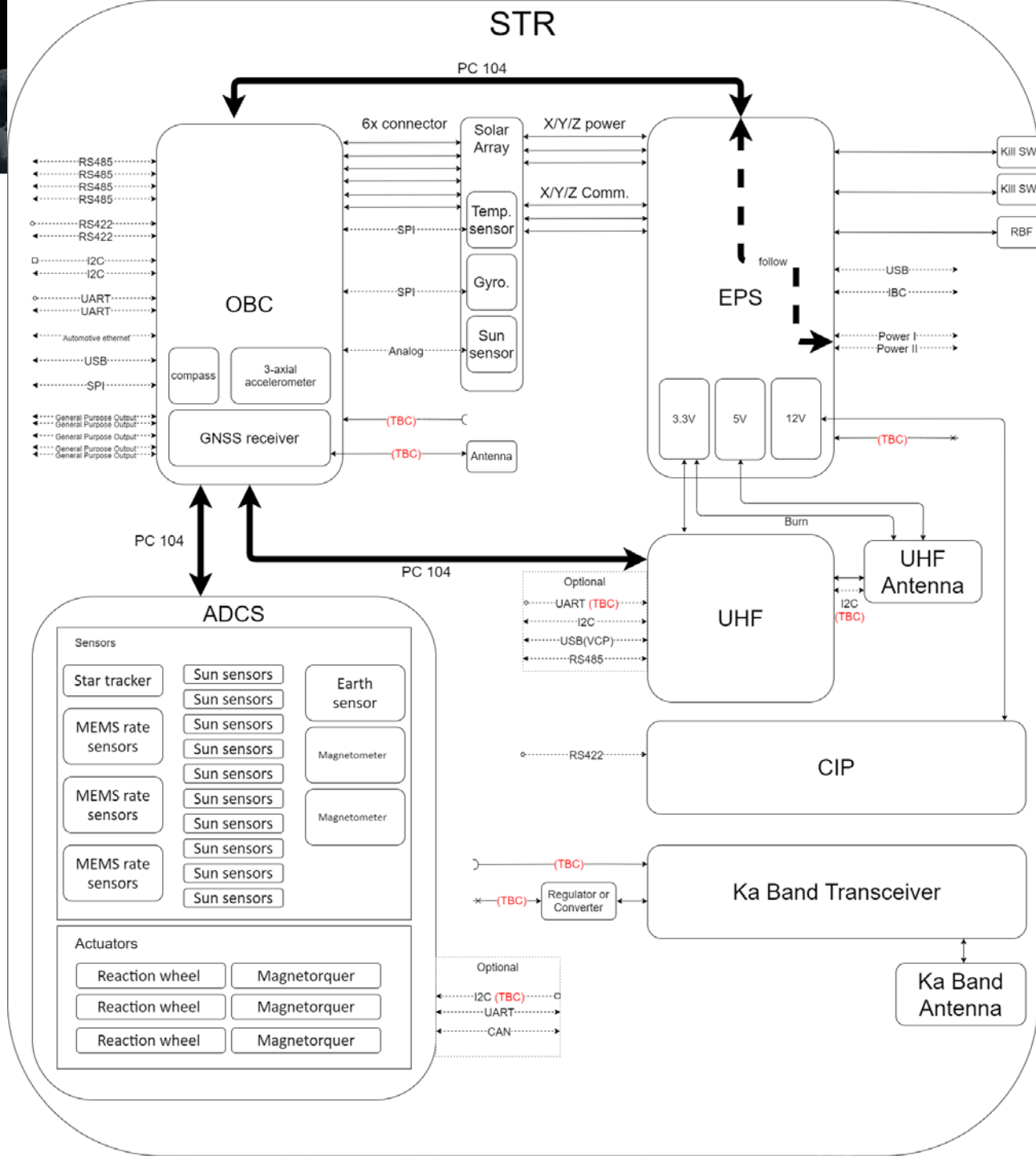
UHF transceiver

- UHF 2U antenna (bottom) + [ UHF 2U antenna + solar panel (top) ]
- Ka-band Tx Antenna + Ka-band Rx Antenna
- UHF Ground Station equipment

## Subsystems (Cont.)

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

# STR





# TT&C Simulation

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

# TT&C Simulation (Cont.)

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

Altitude: 550 km

LTDN:0900

Elevation angle: 30 deg

	times	Start	End	Period (min)
Min Duration	3	2 Jan 2022 00:37:47.634	2 Jan 2022 00:38:28.166	0.676
Max Duration	25	21 Jan 2022 01:06:50.073	21 Jan 2022 01:10:36.621	3.776
Mean Duration				2.978
Total Duration				125.079

# Mass Budget

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

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



# 會議記錄與回條

- 記得MDR時有人記錄或錄音錄影。
- 問題統整要回覆給與會者。

MDR\_SDR問題回條\_final.pdf - Adobe Acrobat Pro

PEARL  
MDR/SDR 回條

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

# 會議記錄與回條 (Cont.)

The screenshot shows a Microsoft Word document titled "MDR\_SDR問題回條\_v2.docx". The document content is a table with the following structure:

排定解決問題時間	問題	回覆	回覆人員	回覆日期
	Overview			
2021.04.14	● 在 overview 加上任務目標	● 這次只以圖示呈現，未來會增加敘述	黃唯蓉	2021.04.03
2021.04.14	● 要放 6U 衛星結構示意	● 未來會補上	黃唯蓉	2021.04.03

The status bar at the bottom indicates: 第 1 頁, 共 11 頁, 2156 個字, 中文 (台灣), 150%.



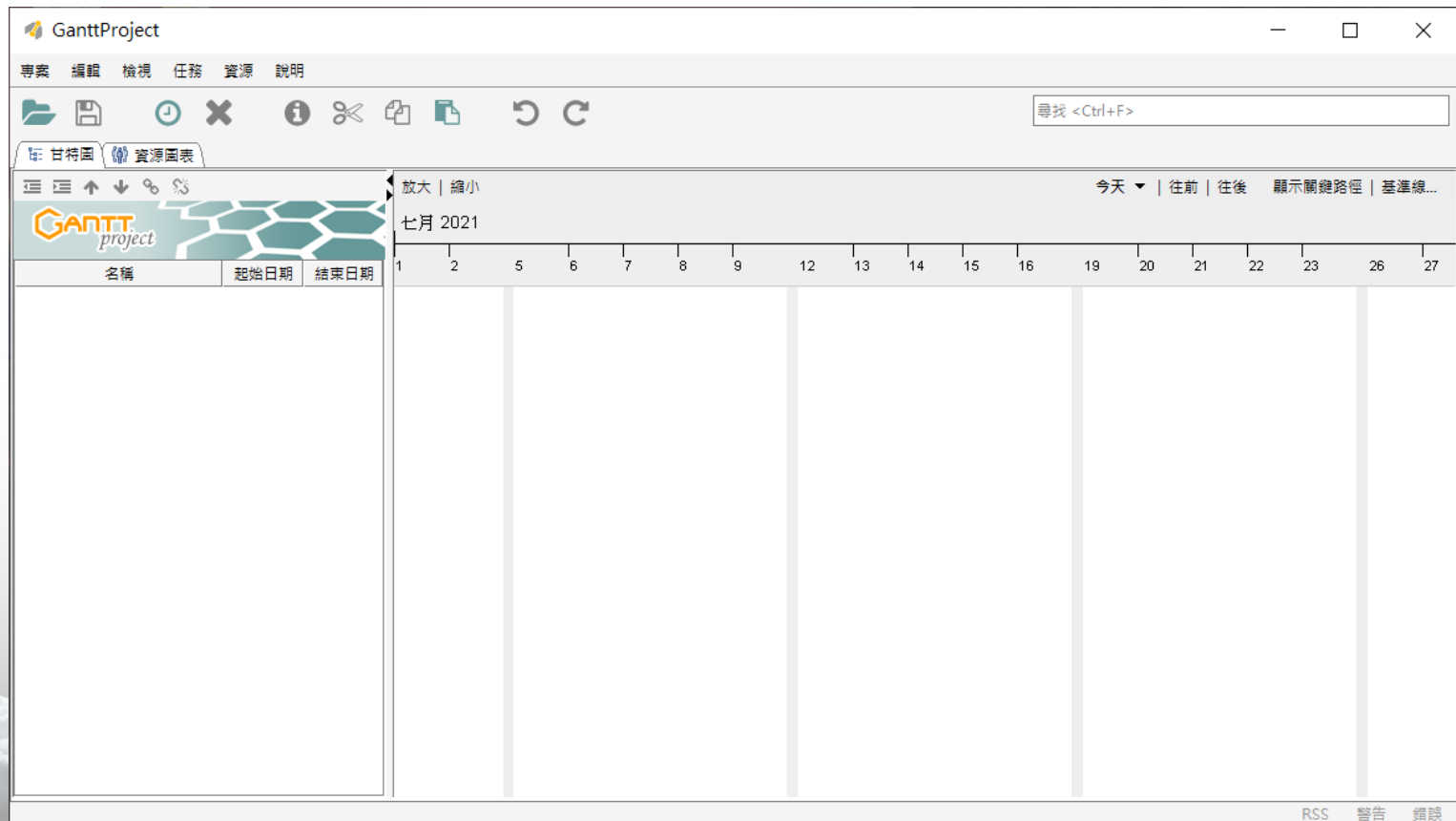
# 03 Application

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

1. GanttProject
2. XMind

# Schedule Software

- GanttProject
- 甘特圖





# XMind

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





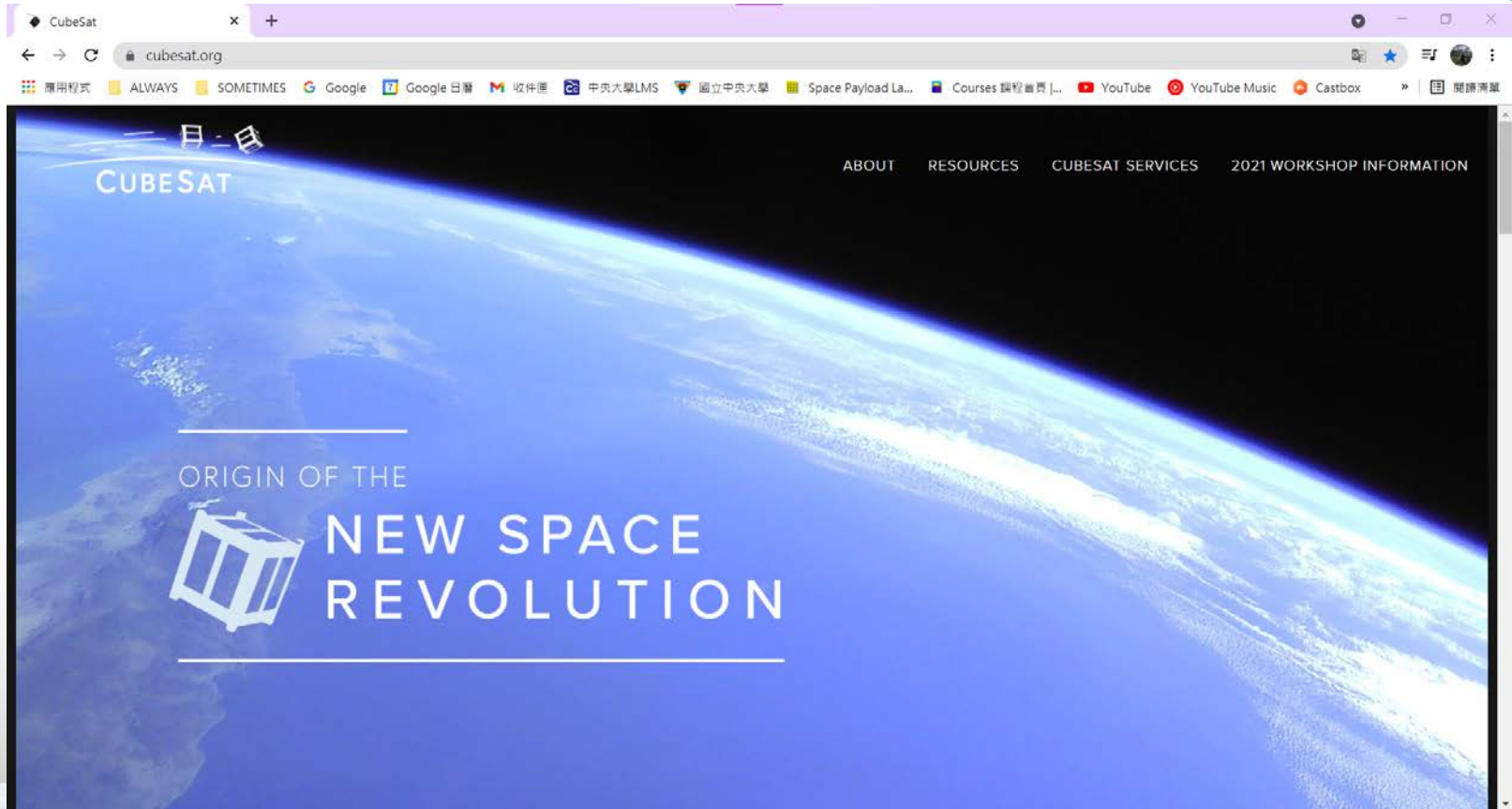
# 04 Reference

The Books and Data about Making the CubeSat.

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

# CubeSat Design Specification

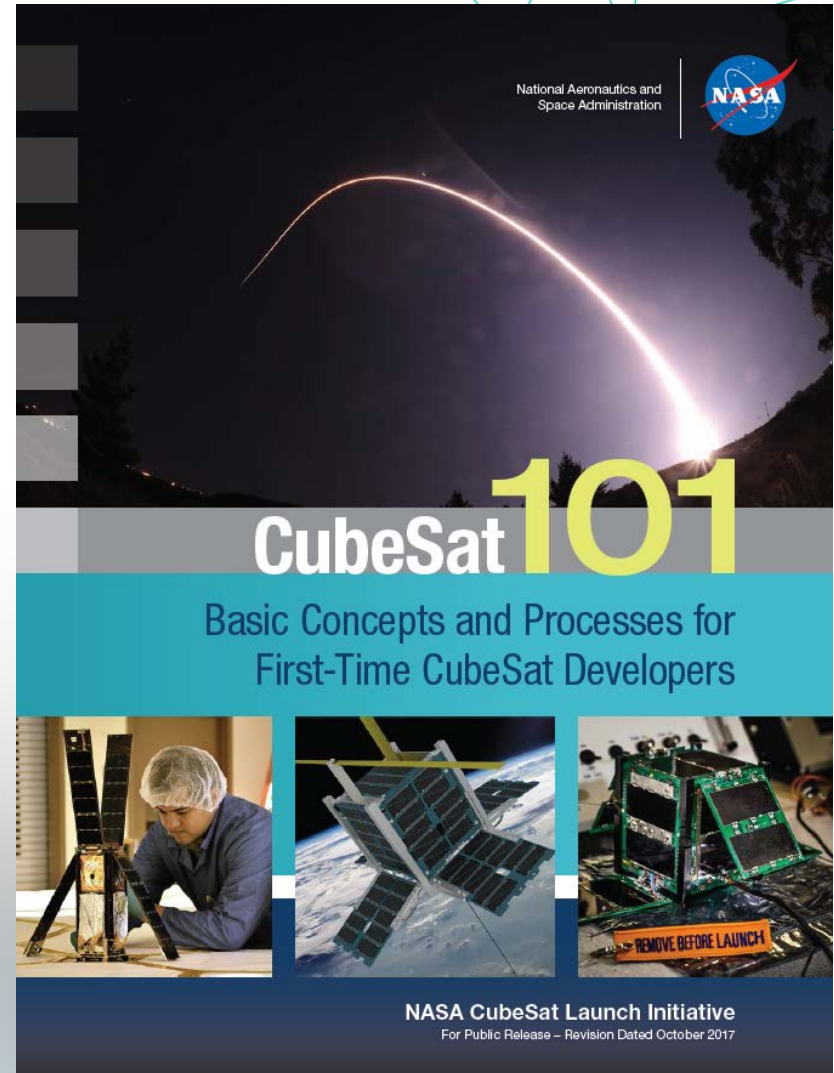
- <https://www.cubesat.org/>





# CubeSat 101

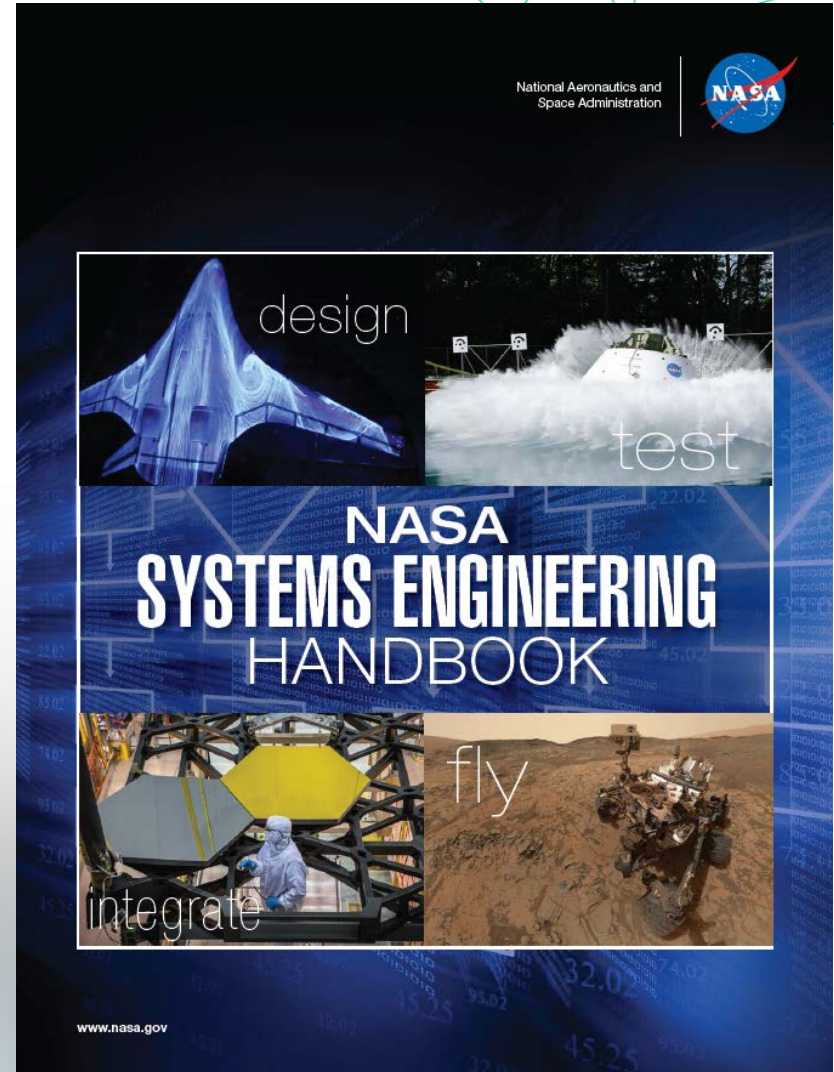
- 製作立方衛星的流程
- 很多美國官方的流程。
- [https://www.nasa.gov/sites/default/files/atoms/files/nasa\\_csli\\_cubesat\\_101\\_508.pdf](https://www.nasa.gov/sites/default/files/atoms/files/nasa_csli_cubesat_101_508.pdf)





# 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。







THANK YOU