Name:

**Enrolment No:** 



## UPES End Semester Examination, December 2024

Course: Rocket Propulsion Program: B.Tech ASE Course Code: ASEG 4011P Semester: VII Time : 03 hrs. Max. Marks: 100

Instructions: All questions are compulsory Assume necessary data if not given.

## SECTION A (5Qx4M=20Marks)

S. No.			Marks	CO	
Q 1	Explain the functioning of gas generative liquid rocket engines. How do these	erator-based propellant feed systems in systems contribute to engine operation?	4	CO1	
Q 2	Describe the role and significance of essential for the operation of the rock	igniters in rocket motors. Why are they tet propulsion system?	4	CO2	
Q 3	In what ways does multi-staging of rockets enhance their performance? Provide a detailed explanation of its contribution to the efficiency of rocket flight.		4	CO3	
Q 4	Discuss the advantages of electrical to chemical rocket engines. What alternative in certain applications?	propulsion engines (thrusters) compared makes electrical propulsion a viable	4	CO4	
Q 5	What are the primary causes of co Discuss methods that can be en instabilities.	mbustion instability in rocket engines? ployed to control or mitigate these	4	CO1	
SECTION B					
	(4Q	x10M= 40 Marks)	[]		
Q 6	Evaluate the modern design approaches used in conducting burn rate studies for solid propellant strands, considering recent advancements such as high- fidelity simulation tools and real-time data collection methods. Discuss how these innovations are integrated into performance estimation tests conducted in state-of-the-art facilities like the Space Technology Lab.		10	CO4	
Q 7	The following measurements were m propellant rocket motor: Burn duration Initial mass before test Mass of rocket motor after test Average thrust	ade in a sea level test of a solid 40 sec 1210kg 215kg 62,250 N	10	CO1	
	Chamber pressure	7.00 MPa			

Nozzle exit pressure       0.070 MPa         Nozzle exit diameter       0.2703 m         Determine mass flow rate (m.), V <sub>2</sub> , C <sup>*</sup> , C, and Is at 1000 and 25000 m         altitude. Assume an invariant thrust and mass flow rate and negligible short start and stop transients. (At 1000, Pa= 0.0898 MPa and At 25000 m, Pa= 0.00255 MPa)         OR         A rocket has a total mass of 5000 kg, including propellant. Its specific impulse is 300 seconds, and its propellant flow rate is 50 kg/s. The rocket is launched vertically upwards and experiences negligible air resistance.         (a) What is the maximum velocity the rocket can achieve? (4 marks)         (b) What is the total impulse of the rocket motor during its entire burn time?         (C) What is the total impulse of the cocket motor during its entire burn time?         (c) What is the total supplemention in jector behavior in the thrust chambers of Liquid Propellant Rocket Engines, especially with respect to innovations fike 3D-printed injectors and advanced materials used in modern rockets. How have these technologies enhanced the efficiency of engines such as the ISRO's GSL V and L/M-3, which are pivotal for launching satellites and crewed space missions?         Q 9       Explain the principles of thrust vector control (TVC) and how it has evolved with the development of modern rockets, such as the integration of fluidic TVC in next generation launch systems like SpaceX's Falcon Heavy or NASA's Space Launch System (SLS).       10       CO3         Q 10       The Saturn V rocket used by NASA during the Apollo missions was a multistage rocket, consisting of thre stages. The first stage used a sin				
Nozzle krota diameter       0.0855 m         Nozzle krota diameter       0.2703 m         Determine mass flow rate (m.), V <sub>2</sub> , C <sup>+</sup> , C, and Is at 1000 and 25000 m       altitude. Assume an invariant thrust and mass flow rate and negligible short start and stop transients. (At 1000, Pa= 0.0898 MPa and At 25000 m, Pa= 0.00255 MPa)         OR       A rocket has a total mass of 5000 kg, including propellant. Its specific impulse is 300 seconds, and its propellant flow rate is 50 kg/s. The rocket is launched vertically upwards and experiences negligible air resistance.         (a) What is the rocket's initial acceleration? (3 marks)       (b) What is the total impulse of the rocket can achieve? (4 marks)         (c) What is the total impulse of the rocket motor during its entire burn time?       (3 marks)         Q 8       Analyze the key factors influencing injector behavior in the thrust chambers of Liquid Propellant Rocket Engines, especially with respect to innovations like 3D-printed injectors and advanced materials used in modern rockets. How have these technologies enhanced the efficiency of engines such as the ISRO's GSLV and LVM-3, which are pivotal for launching satellites and crewed space missions?       10       C01         Q 9       EXplain the principles of thrust vector control (TVC) and how it has evolved with the development of modern rockets, such as the integration of fluidic TVC in next generation launch systems like SpaceX's Falcon Heavy or NASA's Space Launch System (SLS).       10       C03         Q 10       The Saturn V rocket used by NASA during the Apollo missions was a multistage rocket, consiting of thre stages. The first stage used a sin		Nozzle exit pressure 0.070 MPa		
Nozzle exit diameter       0.2703 m       0.2703 m         Determine mass flow rate (m.), V2, C <sup>2</sup> , c., cal Is at 1000 and 25000 m       altitude. Assume an invariant thrust and mass flow rate and negligible short start and stop transients. (At 1000, Pa= 0.0898 MPa and At 25000 m, Pa= 0.00255 MPa)       0.00         A rocket has a total mass of 5000 kg, including propellant. Its specific impulse is 300 seconds, and its propellant flow rate is 50 kg/s. The rocket is launched vertically upwards and experiences negligible air resistance.       (a) What is the rocket's initial acceleration? (3 marks)         (b) What is the total impulse of the rocket can achieve? (4 marks)       (c) What is the total impulse of the rocket can achieve? (a marks)         (c) What is the total inpulse of the rocket motor during its entire burn time?       (3 marks)         (c) What is the total inpulse of the rocket motor during its entire burn time?       10         C01       Sign arks)       10         C03       SGLV and LVM-3, which are pivotal for launching satellites and crewed space missions?       10         C14 out Propellant Rocket Engines, sepecially with respect to innovations thus Sign SGLV and LVM-3, which are pivotal for launching satellites and crewed space missions?       10         C29       Explain the principles of throst vector control (TVC) and how it has evolved with the development of modern rockets, such as the integration of fluidic TVC in next generation launch systems like SpaceX's Falcon Heavy or NASA's Space Launch System (SLS).       10       CO3         Q 10       The		Nozzle throat diameter 0.0855 m		
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altitude. Assume an invariant thrust and mass flow rate and negligible short start and stop transients. (At 1000, Pa= 0.0898 MPa and At 25000 m, Pa= 0.00255 MPa)       OR         A rocket has a total mass of 5000 kg. including propellant. Its specific impulse is 300 seconds, and its propellant flow rate is 50 kg/s. The rocket is launched vertically upwards and experiences negligible air resistance.       (a) What is the rocket's initial acceleration (?3 <b>marks</b> )         (b) What is the total impulse of the rocket motor during its entire burn time?       (3 <b>marks</b> )         (c) What is the total impulse of the rocket to moder mockets. How have these technologies enhanced the efficiency of engines such as the ISRO's GSLV and LVM-3, which are pivotal for launching satellites and crewed space missions?       10         Q 9       Explain the principles of throust vector control (TVC) and how it has evolved with the development of modern rockets, such as the integration of fluidic TVC in next generation launch systems like SpaceX's Falcon Heavy or NASA's Space Launch System (SLS).       10       C03         SECTION-C (2Qx20M=40 Marks)         Q 10       The Saturn V rocket used by NASA during the Apollo missions was a multistage rocket, consisting of three stage. She fairst stage used five F-1 engines, the second stage used five J-2 engines, fuel, and performance parameters. (6 marks)       20       C04         (c) The Saturn V rocket thad a total height of 110 meters and a liftoff mass of 2.8 million newtons and a specific impulse of 263 seconds, what was its total impulse? (4 marks)       20       C04         (d) The Saturg V scoke tha a specific impulse of 263 s		Determine mass flow rate (m.), $V_2$ , $C^*$ , C, and Is at 1000 and 25000 m		
start and stop transients. (At 1000, Pa= 0.0898 MPa and At 25000 m, Pa= 0.00255 MPa)       OR         A rocket has a total mass of 5000 kg, including propellant. Its specific impulse is 300 seconds, and its propellant flow rate is 50 kg/s. The rocket is launched vertically upwards and experiences negligible air resistance.       (a) What is the rocket's initial acceleration? (3 marks)         (b) What is the total impulse of the rocket can achieve? (4 marks)       (c) What is the total impulse of the rocket motor during its entire burn time?         (c) What is the total impulse of the rocket motor during its entire burn time?       (3 marks)         Q 8       Analyze the key factors influencing injector behavior in the thrust chambers of Liquid Propellant Rocket Engines, especially with respect to innovations like 3D-printed injectors and advanced materials used in modern rockets. How have these technologies enhanced the efficiency of engines such as the ISRO's GSLV and LVM-3, which are pivotal for launching satellites and crewed space missions?       10       CO1         Q 9       Explain the principles of thrust vector control (TVC) and how it has evolved with the development of modern rockets, such as the integration of fluidic TVC in next generation launch systems like SpaceX's Falcon Heavy or NASA's Space Launch System (SLS).       10       CO3         Q 10       The Saturn V rocket used by NASA during the Apollo missions was a multistage rocket, onsisting of three stages. The first stage used a single J-2 engine. The rocket had a total height of 110 meters and a liftoff mass of 2.8 million kg.       20       CO4         (b) The first stage of the Saturn V rocket burned for approxi		altitude. Assume an invariant thrust and mass flow rate and negligible short		
0.00255 MPa)       OR         A rocket has a total mass of 5000 kg, including propellant. Its specific impulse is 300 seconds, and its propellant flow rate is 50 kg/s. The rocket is launched vertically upwards and experiences negligible air resistance. <ul> <li>(a) What is the rocket's initial acceleration? (3 marks)</li> <li>(b) What is the total impulse of the rocket can achieve? (4 marks)</li> <li>(c) What is the total impulse of the rocket motor during its entire burn time?</li> <li>(3 marks)</li> <li>Q 8</li> <li>Analyze the key factors influencing injector behavior in the thrust chambers of Liquid Propellant Rocket Engines, especially with respect to innovations like 3D-printed injectors and advanced materials used in modern rockets. How have these technologies enhanced the efficiency of engines such as the ISRO's GSLV and LVM-3, which are pivotal for launching satellites and crewed space missions?</li> <li>Q 9</li> <li>Explain the principles of thrust vector control (TVC) and how it has evolved with the development of modern rockets, such as the integration of fluidic TVC in next generation launch systems like SpaceX's Falcon Heavy or NASA's Space Launch System (SLS).</li> <li>SECTION-C (2Qx20M=40 Marks)</li> <li>Q 10</li> <li>The Saturn V rocket used by NASA during the Apollo missions was a multistage rocket, consisting of three stages. The first stage used five F-1 engines, the second stage used five J-2 engines, and the drid stage used a single J-2 engine. The rocket had a total height of 110 meters and a liftoff mass of 2.8 million kg.</li> <li>(a) Compare and contrast the design of the first, second, and third stage used a single J-2 engine. The rocket burned for approximately 2.5 minutes before separating from the rest of the rocket. If the first stage had a thrust of 34 million newtons and a specific impulse of 421 seconds, what was its total impulse? (4 m</li></ul>		start and stop transients. (At 1000, Pa= 0.0898 MPa and At 25000 m, Pa=		
OR       A rocket has a total mass of 5000 kg, including propellant. Its specific impulse is 300 seconds, and its propellant flow rate is 50 kg/s. The rocket is launched vertically upwards and experiences negligible air resistance. <ul> <li>(a) What is the maximum velocity the rocket can achive? (4 marks)</li> <li>(b) What is the total impulse of the rocket motor during its entire burn time?</li> <li>(c) What is the total impulse of the rocket can achive? (4 marks)</li> <li>(c) What is the total impulse of the rocket motor during its entire burn time?</li> <li>(d) marks)</li> <li>Q 8</li> <li>Analyze the key factors influencing injector behavior in the thrust chambers of Liquid Propellant Rocket Engines, especially with respect to innovations like 3D-printed injectors and advanced materials used in modern rockets. How have these technologies enhanced the efficiency of engines such as the ISRO's GSLV and LVM-3, which are pivotal for launching satellites and crewed space missions?</li> <li>Q 9</li> <li>Explain the principles of thrust vector control (TVC) and how it has evolved with the development of modern rockets, such as the integration of fluidic TVC in next generation launch systems like SpaceX's Falcon Heavy or NASA's Space Launch System (SLS).</li> <li>I0</li> <li>C03</li> <li>Q 10</li> <li>The Saturn V rocket used by NASA during the Apollo missions was a multistage rocket, consisting of three stages. The first stage used a single J-2 engine. The rocket had a total height of 110 meters and a liftoff mass of 2.8 million kg.</li> <li>(a) Compare and contrast the design of the first, second, and third stages of the Saturn V rocket burned for approximately 2.5 minutes before separating from the rest of the rocket. If the first stage had a thrust of 34 million newtons and a specific impulse of 421 seconds, what was its total impulse? (4 marks)</li> <li>(c) The second stage of</li></ul>		0.00255 MPa)		
A rocket has a total mass of 5000 kg, including propellant. Its specific         impulse is 300 seconds, and its propellant flow rate is 50 kg/s. The rocket is         launched vertically upwards and experiences negligible air resistance.         (a) What is the rocket's initial acceleration? ( <b>3 marks</b> )         (b) What is the total impulse of the rocket motor during its entire burn time?         (3 marks)         Q 8         Analyze the key factors influencing injector behavior in the thrust chambers of Liquid Propellant Rocket Engines, especially with respect to innovations like 3D-printed injectors and advanced materials used in modern rockets. How have these technologies enhanced the efficiency of engines such as the ISRO's GSLV and LVM-3, which are pivotal for launching satellites and crewed space missions?       10       CO1         Q 9       Explain the principles of thrust vector control (TVC) and how it has evolved with the development of modern rockets, such as the integration of fluidic TVC in next generation launch systems like SpaceX's Falcon Heavy or NASA's Space Launch System (SLS).       10       CO3         SECTION-C (2Q20M-40 Marks)         Q 10       The Saturn V rocket used by NASA during the Apollo missions was a multistage rocket, consisting of thre stages. The first stage used five F-1 engines, the second stage used five J-2 engines, and the did stage of the first, second, and third stages of the Saturn V rocket in terms of their engines, fuel, and performance parameters. (6 marks)       20       CO4         (b) The first stage of the Saturn V rocket burned for approximately 2.5 minutes before		OR		
impulse is 300 seconds, and its propellant flow rate is 50 kg/s. The rocket is launched vertically upwards and experiences negligible air resistance.       (a) What is the rocket's initial acceleration? ( <b>3 marks</b> )         (b) What is the total impulse of the rocket can achieve? ( <b>4 marks</b> )       (c) What is the total impulse of the rocket can achieve? ( <b>4 marks</b> )         (c) What is the total impulse of the rocket motor during its entire burn time?       ( <b>3 marks</b> )         (a) What is the total impulse of the rocket motor during its entire burn time?       ( <b>3 marks</b> )         (d) What is the total impulse of the rocket motor during its entire burn time?       ( <b>3 marks</b> )         (d) What is the total inpulse of the rocket materials used in modern rockets. How have these technologies enhanced the efficiency of engines such as the ISRO's GSL V and LVM-3, which are pivotal for launching satellites and crewed space missions?       10         Q 9       Explain the principles of thrust vector control (TVC) and how it has evolved with the development of modern rockets, such as the integration of fluidic TVC in next generation launch systems like SpaceX's Falcon Heavy or NASA's Space Launch System (SLS).       10       CO3         Q 10       The Saturn V rocket used by NASA during the Apollo missions was a multistage rocket, consisting of thre stages. The first stage used five F-1 engines, the second stage used five J-2 engines, and the third stages of the Saturn V rocket had a total height of 110 meters and a liftoff mass of 2.8 million kg.       20       CO4         (e) Compare and contrast the design of the first, second, and third stages of the Saturn V rocket burned for a		A rocket has a total mass of 5000 kg, including propellant. Its specific		
Iaunched vertically upwards and experiences negligible air resistance.       (a) What is the rocket's initial acceleration? (3 marks)         (b) What is the maximum velocity the rocket can achieve? (4 marks)       (c) What is the total impulse of the rocket motor during its entire burn time?         (c) What is the total impulse of the rocket can achieve? (4 marks)       (c) What is the total impulse of the rocket motor during its entire burn time?         (d) marks)       (G) What is the total impulse of the rocket can achieve? (4 marks)       10         (d) What is the total inpulse of the rocket can achieve? (4 marks)       10         (e) What is the total inpulse of thrust vector control (TVC) and how it has evolved with the development of modern rockets, such as the integration of fluidic TVC in next generation launch systems like SpaceX's Falcon Heavy or NASA's Space Launch System (SLS).       10       CO3         Q 10       The Saturn V rocket used by NASA during the Apollo missions was a multistage rocket, consisting of three stages. The first stage used a single J-2 engine. The rocket had a total height of 110 meters and a liftoff mass of 2.8 million kg.       20       CO4         (a) Compare and contrast the design of the first, second, and third stages of the Saturn V rocket in terms of their engines, fuel, and performance parameters. (6 marks)       20       CO4         (b) The first stage of the Saturn V rocket burned for approximately 2.5 minutes before separating from the rest of the rochect. If the first stage had a thrust of 34 million newtons and a specific impulse of 421 seconds, what was its total impulse? (4 marks)       20		impulse is 300 seconds, and its propellant flow rate is 50 kg/s. The rocket is		
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(b) What is the maximum velocity the rocket can achieve? (4 marks)       (c) What is the total impulse of the rocket motor during its entire burn time?         (3 marks)       (3 marks)         Q 8       Analyze the key factors influencing injector behavior in the thrust chambers of Liquid Propellant Rocket Engines, especially with respect to innovations like 3D-printed injectors and advanced materials used in modern rockets. How have these technologies enhanced the efficiency of engines such as the ISRO's GSLV and LVM-3, which are pivotal for launching satellites and crewed space missions?       10       CO1         Q 9       Explain the principles of thrust vector control (TVC) and how it has evolved with the development of modern rockets, such as the integration of fluidic TVC in next generation launch systems like SpaceX's Falcon Heavy or NASA's Space Launch System (SLS).       10       CO3         Q 10       The Saturn V rocket used by NASA during the Apollo missions was a multistage rocket, consisting of three stages. The first stage used five F-1 engines, the second stage used five J-2 engine, and the third stage used a single J-2 engine. The rocket had a total height of 110 meters and a liftoff mass of 2.8 million kg.       20       CO4         (a) Compare and contrast the design of the first, second, and third stage sof the Saturn V rocket burned for approximately 2.5 minutes before separating from the rest of the rocket. If the first stage had a thrust of 34 million newtons and a specific impulse of 263 seconds, what was its total impulse? (4 marks)       20       CO4         (d) If the third stage of the Saturn V rocket burned for approximately 6 minuses before separating from the rest of the rocket. I		(a) What is the rocket's initial acceleration? ( <b>3 marks</b> )		
(c) What is the total impulse of the rocket motor during its entire burn time?       (3 marks)         Q 8       Analyze the key factors influencing injector behavior in the thrust chambers of Liquid Propellant Rocket Engines, especially with respect to innovations like 3D-printed injectors and advanced materials used in modern rockets. How have these technologies enhanced the efficiency of engines such as the ISRO'S GSLV and LVM-3, which are pivotal for launching satellites and crewed space missions?       10       CO1         Q 9       Explain the principles of thrust vector control (TVC) and how it has evolved with the development of modern rockets, such as the integration of fluidic TVC in next generation launch systems like SpaceX's Falcon Heavy or NASA's Space Launch System (SLS).       10       CO3         SECTION-C (2Qx20M=40 Marks)         (2 9       Staturn V rocket used by NASA during the Apollo missions was a multistage rocket, consisting of three stages. The first stage used five F-1 engines, the second stage used five J-2 engines, and the third stage used a single J-2 engine. The rocket had a total height of 110 meters and a liftoff mass of 2.8 million kg.       10       CO4         (a) Compare and contrast the design of the first, second, and third stages of the Saturn V rocket in terms of their engines, fuel, and performance parameters. (6 marks)       20       CO4         (b) The first stage of the Saturn V rocket burned for approximately 2.5 minutes before separating from the rest of the rocket. If the first stage had a thrust of 34 million newtons and a specific impulse of 263 seconds, what was its total impulse? (4 marks)       20       CO4      <		(b) What is the maximum velocity the rocket can achieve? (4 marks)		
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Q 8       Analyze the key factors influencing injector behavior in the thrust chambers of Liquid Propellant Rocket Engines, especially with respect to innovations like 3D-printed injectors and advanced materials used in modern rockets. How have these technologies enhanced the efficiency of engines such as the ISRO's GSLV and LVM-3, which are pivotal for launching satellites and crewed space missions?       10       CO1         Q 9       Explain the principles of thrust vector control (TVC) and how it has evolved with the development of modern rockets, such as the integration of fluidic TVC in next generation launch systems like SpaceX's Falcon Heavy or NASA's Space Launch System (SLS).       10       CO3         SECTION-C (2Qx20M=40 Marks)         Q 10       The Saturn V rocket used by NASA during the Apollo missions was a multistage rocket, consisting of three stages. The first stage used five F-1 engines, the second stage used five J-2 engines, and the third stage used a single J-2 engine. The rocket had a total height of 110 meters and a liftoff mass of 2.8 million kg.       20       CO4         (a) Compare and contrast the design of the first, second, and third stages of the Saturn V rocket in terms of their engines, fuel, and performance parameters. (6 marks)       20       CO4         (b) The first stage of the Saturn V rocket burned for approximately 6       minutes before separating from the rest of the rocket. If the first stage had a thrust of 34 million newtons and a specific impulse of 421 seconds, what was its total impulse? (4 marks)       20       CO4         (d) If the third stage of the Saturn V rocket had a thrust of 1 million newtons and a specific impulse of 421 seconds, w		(3 marks)		
of Liquid Propellant Rocket Engines, especially with respect to innovations like 3D-printed injectors and advanced materials used in modern rockets. How have these technologies enhanced the efficiency of engines such as the ISRO's GSLV and LVM-3, which are pivotal for launching satellites and crewed space missions?10CO1Q 9Explain the principles of thrust vector control (TVC) and how it has evolved with the development of modern rockets, such as the integration of fluidic TVC in next generation launch systems like SpaceX's Falcon Heavy or NASA's Space Launch System (SLS).10CO3C03SECTION-C (2Qx20M=40 Marks)Q 10The Saturn V rocket used by NASA during the Apollo missions was a multistage rocket, consisting of three stages. The first stage used five F-1 engines, the second stage used five J-2 engines, and the third stage used a single J-2 engine. The rocket had a total height of 110 meters and a liftoff mass of 2.8 million kg. (a) Compare and contrast the design of the first, second, and third stages of the Saturn V rocket in terms of their engines, fuel, and performance parameters. (6 marks) (b) The first stage of the Saturn V rocket burned for approximately 2.5 minutes before separating from the rest of the rocket. If the first stage had a thrust of 34 million newtons and a specific impulse of 263 seconds, what was its total impulse? (4 marks) (c) The second stage of the Saturn V rocket burned for approximately 6 minutes before separating from the rest of the rocket. If the second stage had a thrust of 5 million newtons and a specific impulse of 421 seconds, what was its total impulse? (4 marks) (d) If the third stage of the Saturn V rocket burned for approximately 6 minutes before separating from the rest of the rocket. If the second stage	Q 8	Analyze the key factors influencing injector behavior in the thrust chambers		
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	OR		
	Critically examine the droplet combustion model used in liquid fuel		
	combustion for modern rocket engines, considering recent advancements in		
	computational simulations. Discuss the conditions under which the shape of		
	the flame front is affected, and how emerging technologies, such as		
	combustion instability mitigation techniques and advanced injector designs,		
	influence flame front dynamics in cutting-edge propulsion systems like those		
	used in ISRO's GSLV or SpaceX's Raptor engine.		
Q 11	Analyze the key design features and innovations of ISRO's Small Satellite		
	Launch Vehicle (SSLV), focusing on its propulsion system, payload capacity		
	and mission flexibility. Discuss the recent SSLV-D2/EOS-07 mission,		
	highlighting its performance and the vehicle's advantages over traditional	20	CO4
	rockets like PSLV in terms of rapid deployment and cost-effectiveness.	20	C04
	Evaluate how the SSLV contributes to ISRO's future space missions and		
	suggest areas for further improvement based on current propulsion		
	technologies.		