

FAARFIELD 1.4

Implementing New Compaction Provisions

Presented to: XI ALACPA Seminar on Airport Pavements and
IX FAA Workshop, Santiago de Chile

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Date: 3 September, 2014



Federal Aviation
Administration



Compaction Requirements

- **FAA design procedures (AC 150/5320-6E) assume that minimum compaction requirements are met.**
- **Subgrade compaction requirements are expressed as a minimum percentage of the maximum dry density by:**
 - ASTM D 1557 (Modified Proctor) for pavements serving airplanes > 27,216 kg (60,000 lbs.) GW.
 - ASTM D 698 (Standard Proctor) for light load pavements (serving airplanes < 27, 216 kg).

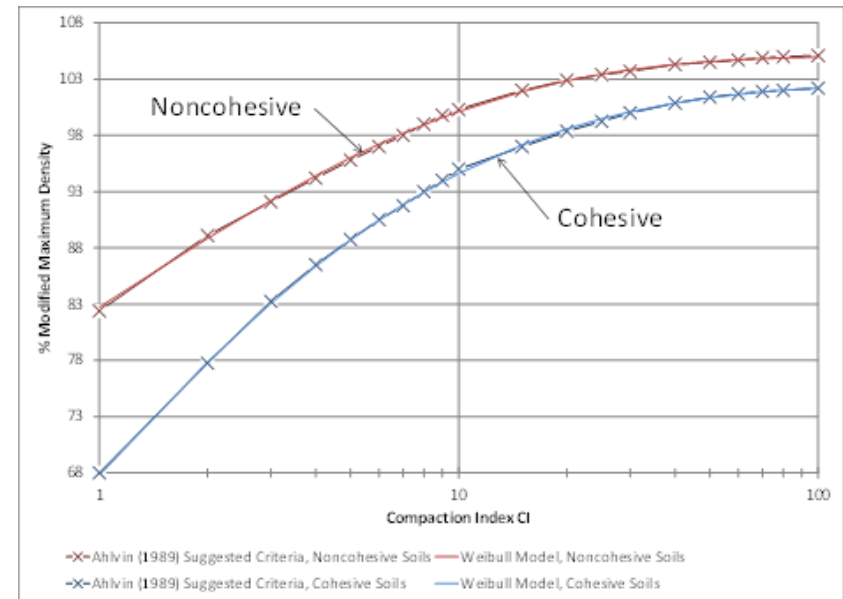
Why Compaction Requirements?

- **Minimum density requirements for soils are intended to prevent additional densification under in-service aircraft traffic.**
- **Curves of minimum required density versus CBR (Compaction Index, CI) were developed from observed field data in the 1950's.***
- **Established separate relationships for cohesive and non-cohesive soil types.**

****See Ahlvin, *Compaction Requirements for Soil Components of Flexible Airfield Pavements*, US Army WES, TR 3-529, 1959.***

Compaction Index (CI)

- **CI is defined as:**
“the CBR required at a given depth for a particular wheel configuration, assembly load and tire pressure.”
- **CI is computed for depth measured from surface.**
- **Proposed criteria developed by Richard Ahlvin were never implemented by the FAA and are not consistent with the current standards in AC 150/5320-6E.**



Suggested criteria for percent modified maximum density as a function of CI, based on Ahlvin (1989)

$$\% \text{ Maximum Density} = a - be^{-c(CI)^d}$$

Current Compaction Requirements

AC 150/5320-6E, Table 3-4

- **Compaction requirements are given in a table, independent of FAARFIELD thickness design.**
- **Control points are referenced to the top of subgrade, regardless of pavement thickness or subgrade CBR. This is theoretically incorrect.**
- **Extrapolation to new large aircraft types (B777 and A380) is not reliable.**

TABLE 3-4. SUBGRADE COMPACTION REQUIREMENTS FOR FLEXIBLE PAVEMENTS

GEAR TYPE	GROSS WEIGHT Lb.	NON-COHESIVE SOILS Depth of Compaction, inch				COHESIVE SOILS Depth of Compaction, inch			
		100%	95%	90%	85%	95%	90%	85%	80%
S	30,000	8	8-18	18-32	32-44	6	6-9	9-12	12-17
	50,000	10	10-24	24-36	36-48	6	6-9	9-16	16-20
	75,000	12	12-30	30-40	40-52	6	6-12	12-19	19-25
D (incls. 2S)	50,000	12	12-28	28-38	38-50	6	6-10	10-17	17-22
	100,000	17	17-30	30-42	42-55	6	6-12	12-19	19-25
	150,000	19	19-32	32-46	46-60	7	7-14	14-21	21-28
	200,000	21	21-37	37-53	53-69	9	9-16	16-24	24-32
2D (incls. B757, B767, A-300, DC-10-10, L1011)	100,000	14	14-26	26-38	38-49	5	6-10	10-17	17-22
	200,000	17	17-30	30-43	43-56	5	6-12	12-18	18-26
	300,000	20	20-34	34-48	48-63	7	7-14	14-22	22-29
	400,000 – 600,000	23	23-41	41-59	59-76	9	9-18	18-27	27-36
2D/D1, 2D/2D1 (incls. MD11, A340, DC10-30/40)	500,000 – 800,000	23	23-41	41-59	59-76	9	9-18	18-27	27-36
2D/2D2 (incls. B747 series)	800,000	23	23-41	41-59	59-76	9	9-18	18-27	27-36
	975,000	24	24-44	44-62	62-78	10	10-20	20-28	28-37
3D (incls. B777 series)	550,000	20	20-36	36-52	52-67	6	6-14	14-21	21-29
	650,000	22	22-39	39-56	56-70	7	7-16	16-22	22-30
	750,000	24	24-42	42-57	57-71	8	8-17	17-23	23-30
2D/3D2 (incls. A380 series)	1,250,000	24	24-42	42-61	61-78	9	9-18	18-27	27-36
	1,350,000	25	25-44	44-64	64-81	10	10-20	20-29	29-38

FAARFIELD 1.4

Automated Compaction Requirements

- **Implements rational compaction criteria based on the CI.**
- **Fully integrated with FAARFIELD 1.4 thickness design.**
 - Compaction criteria are computed at design time based on the design traffic mix.
 - Output in tabular form as part of the design report.
- **Displays compaction control points with respect to both pavement surface and top of subgrade.**

7 Steps to Compute the Compaction Requirement Automatically

1. For 6000 annual departures of a given aircraft, use FAARFIELD to compute vertical stress (layered elastic) and the pass-to-coverage ratio (P/C) at each depth of interest.
2. At each depth z of interest, compute coverages $C = 6000 / (P/C)$.
3. At each depth z of interest, compute the stress ratio

$$S_{3.2}(z) = \frac{1}{\sqrt{u} - 1} \text{ where } u = 1 + \left(\frac{r}{z}\right)^2 \text{ and } r \text{ is the radius of one wheel.}$$

4. The equivalent stress for computing CI is the product of the vertical stress in step 1 and the ratio in step 3.
5. Compute β from $\log(\beta) = \frac{1.7782 + 0.2397 \log(C)}{1 + 0.5031 \log(C)}$ (Gonzalez, 2012).
6. Compute $CI = \frac{\sigma_z^{(n=2)} \times \pi}{\beta}$.
7. Determine the compaction requirement from the appropriate curve.

Example – Flexible Design

Consider the previous flexible pavement design example:

- 10-aircraft mix including A380, B777-300 ER, B787, etc.
- Stabilized pavement design consistent with FAA standards.

The screenshot displays the FAARFIELD v 1.41 Beta software interface for modifying and designing a flexible pavement section. The window title is "FAARFIELD v 1.41 Beta - Modify and Design Section NewFlexible in Job PROJECT".

The main design area shows a table of pavement layers with the following data:

Layer Material	Thickness (mm)	Modulus or R (MPa)
P-401/P-403 HMA Surface	100.0	1,378.95
P-401/P-403 St (flex)	127.0	2,757.90
P-209 Cr Ag	561.5	493.97
Subgrade	CBR = 8.0	82.74

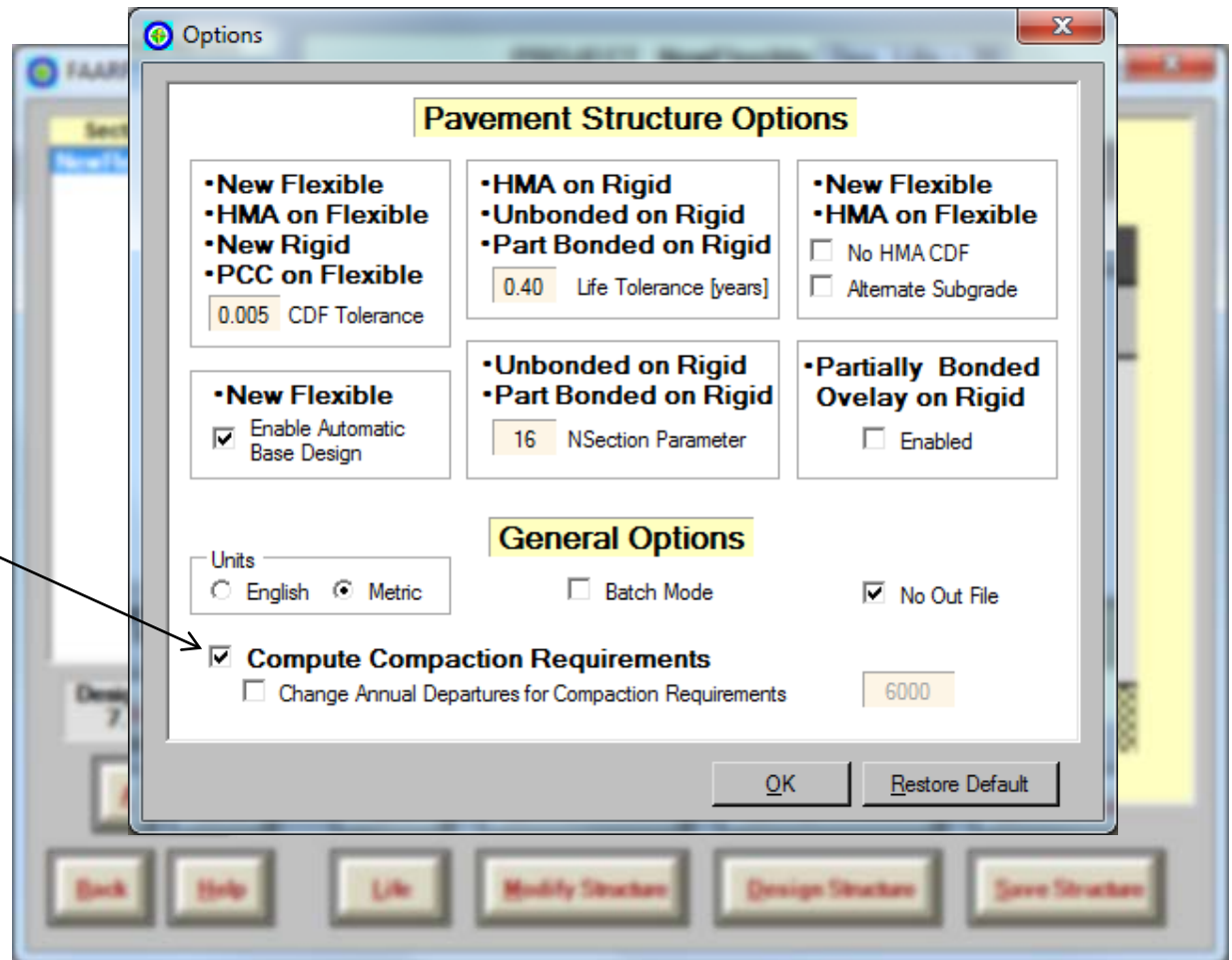
Additional information shown in the interface includes:

- PROJECT: NewFlexible
- Des. Life = 20
- Design Stopped: 7.10; 4.62
- Total thickness to the top of the subgrade, $t = 788.5$ mm

The interface also features a "Section Names" list on the left containing "NewFlexible", a "Design Stopped" status box, an "Airplane" button, and a row of navigation buttons: "Back", "Help", "Life", "Modify Structure", "Design Structure", and "Save Structure".

Compute Compaction

- Hit Alt-O to bring up the Options screen.
- Check the box labeled “Compute Compaction Requirements”
- Click OK



Compute Compaction

FAARFIELD v 1.41 Beta - Modify and Design Section NewFlexible in Job PROJECT

Section Names
NewFlexible

PROJECT NewFlexible Des. Life = 20

Layer Material	Thickness (mm)	Modulus or R (MPa)
P-401/P-403 HMA Surface	100.0	1,378.95
P-401/P-403 St (flex)	127.0	2,757.90
P-209 Cr Ag	561.5	493.97
Subgrade	CBR = 8.0	82.74

Total thickness to the top of the subgrade, t = 788.5 mm

Design Stopped 7.10; 4.62

Airplane

Back Help Life Modify Structure Design Structure Save Structure

Click the "Life" Button.

Compute Compaction

FAARFIELD v 1.41 Beta - Modify and Design Section NewFlexible in Job PROJECT

Section Names
NewFlexible

PROJECT NewFlexible Des. Life = 20

Layer Material	Thickness (mm)	Modulus or R (MPa)
P-401/P-403 HMA Surface	100.0	1,378.95
P-401/P-403 St (flex)	127.0	2,757.90
P-209 Cr Ag	561.5	493.97
Subgrade	CBR = 8.0	82.74

HMA CDF = 0.08; Sub CDF = 1.00; Str Life (SG) = 20.0 yrs; t = 788.5 mm

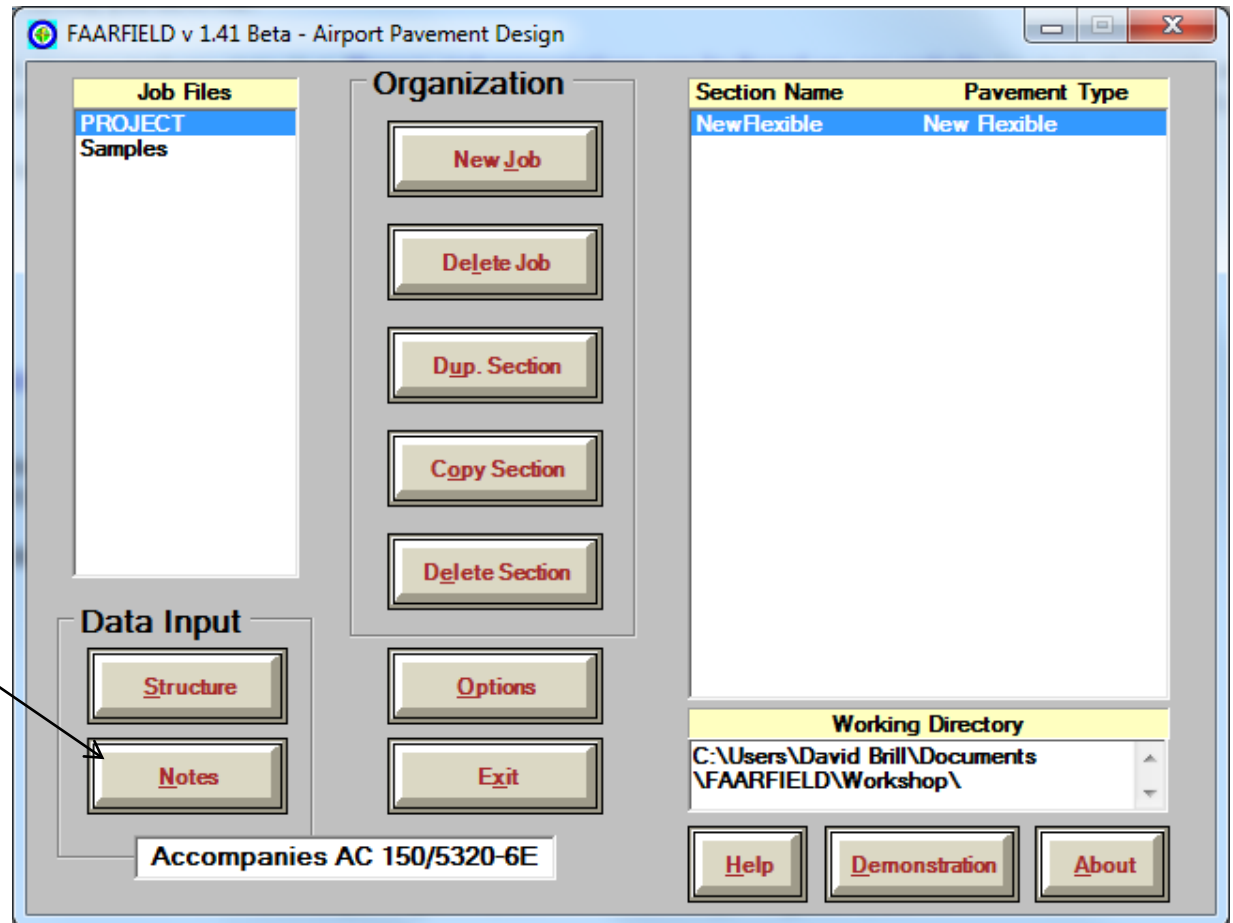
Life Stopped 17.86; 16.63

Airplane

Back Help Life Modify Structure Design Structure Save Structure

Click "Back" to return to the main screen.

Compute Compaction



Select "Notes" to display the design report.

Compute Compaction

Scroll down until the heading “Subgrade Compaction Requirements” is displayed.

Two tables display the compaction requirements for non-cohesive and cohesive soils, respectively.

Compaction depths here given in mm.

The screenshot shows the 'Design Information for Section NewFlexible' window. On the left, a 'Section Names' list has 'NewFlexible' selected. The main area displays 'Subgrade Compaction Requirements' for 'NonCohesive Soil' and 'Cohesive Soil'. Each soil type has a table with columns for 'Percent Maximum Dry Density(%)', 'Depth of compaction from pavement surface (mm)', 'Depth of compaction from top of subgrade (mm)', and 'Critical Airplane for Compaction'. Below the tables are 'Subgrade Compaction Notes' and a row of buttons: 'Help', 'Back', 'Save XML', 'Save', 'Print', 'Design Info', 'Notes', and 'Copy'.

Design Information for Section NewFlexible			
Subgrade Compaction Requirements			
NonCohesive Soil			
Percent Maximum Dry Density(%)	Depth of compaction from pavement surface (mm)	Depth of compaction from top of subgrade (mm)	Critical Airplane for Compaction
100	0 - 1080	0 - 292	B777-300 ER
95	1080 - 3029	292 - 2241	A380

Cohesive Soil			
Percent Maximum Dry Density(%)	Depth of compaction from pavement surface (mm)	Depth of compaction from top of subgrade (mm)	Critical Airplane for Compaction
95	0 - 944	0 - 155	B777-300 ER
90	944 - 2258	155 - 1469	B777-300 ER
85	2258 - 3886	1469 - 3097	A380

Subgrade Compaction Notes:
1. Noncohesive soils, for the purpose of determining compaction control, are those with a plasticity index (PI) less than 3.
2. Tabulated values indicate depth ranges within which densities should equal or exceed the indicated percentage of the maximum dry density as specified in item P-

Compaction Tables

Percent of Max. Dry Density

Depth from Surface

Depth from Top of Subgrade

Critical Airplane for Compaction

Subgrade Compaction Requirements

NonCohesive Soil

Percent Maximum Dry Density(%)	Depth of compaction from pavement surface (mm)	Depth of compaction from top of subgrade (mm)	Critical Airplane for Compaction
100	0 - 1080	0 - 292	B777-300 ER
95	1080 - 3029	292 - 2241	A380

Cohesive Soil

Percent Maximum Dry Density(%)	Depth of compaction from pavement surface (mm)	Depth of compaction from top of subgrade (mm)	Critical Airplane for Compaction
95	0 - 944	0 - 155	B777-300 ER
90	944 - 2258	155 - 1469	B777-300 ER
85	2258 - 3886	1469 - 3097	A380

Subgrade Compaction Notes:

1. Noncohesive soils, for the purpose of determining compaction control, are those with a plasticity index (PI) less than 3.
2. Tabulated values indicate depth ranges within which densities should equal or exceed the indicated percentage of the maximum dry density as specified in item P-152.
3. Maximum dry density is determined using ASTM Method D 1557.
4. The subgrade in cut areas should have natural densities shown or should (a) be compacted from the surface to achieve the required densities, (b) be removed and replaced at the densities shown, or (c) when economics and grades permit, be covered with sufficient select or subbase material so that the uncompacted subgrade is at a depth where the in-place densities are satisfactory.
5. For swelling soils refer to AC 150/5320-6E paragraph 313.

Modified Proctor (Heavy Load)

Compaction Example

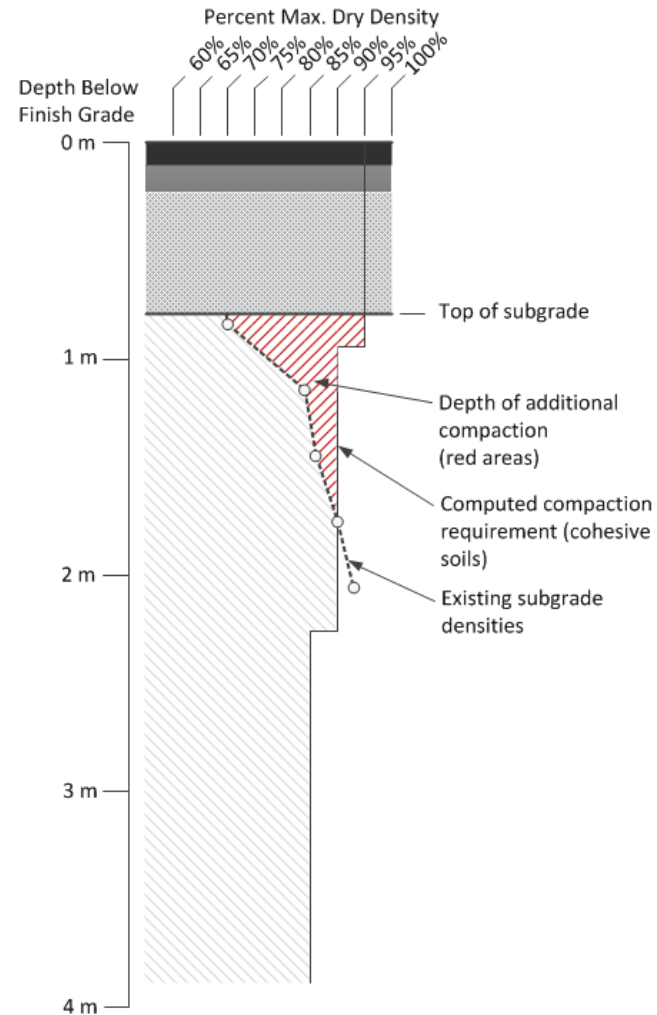
For the flexible design example above, assume:

- Top of subgrade will be approximately 250 mm (10 inches) below the existing ground surface.
- In-place soils have PI = 20 (cohesive).
- Investigation shows the following in-place soil densities in this area:

Depth Below Existing Grade	Depth Below Top of Subgrade	Depth Below Finish Grade	In-Place Density
0.3 m (1 ft.)	0.05 m	0.85 m	70%
0.6 m (2 ft.)	0.350 m	1.15 m	84%
0.9 m (3 ft.)	0.650 m	1.45 m	86%
1.2 m (4 ft.)	0.950 m	1.75 m	90%
1.5 m (5 ft.)	1.250 m	2.05 m	93%

Compaction Example

- Use the FAARFIELD 1.4 generated table for cohesive soils.
- In-place density is satisfactory at a depth of 1.75 m below finish grade (.95 m below top of subgrade).
- Compact the top 16 cm to 95% and 16-95 cm to 90% max. density.



Richard G. Ahlvin 1919-2014

Dick Ahlvin, who retired from the US Army Waterways Experiment Station in 1983, passed away on August 26, 2014. He will be remembered for his deep knowledge and many contributions to the field of airport pavement engineering.



Richard G. Ahlvin

Thank You! ¡Muchas Gracias!

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Acknowledgments:

FAA Airport Technology R&D Branch:

Dr. Michel Hovan, Branch Manager;

Jeff Gagnon, Airport Pavement Section Manager;

Dr. Navneet Garg; Al Larkin; Dr. Charles Ishee; Murphy Flynn; Ryan Rutter; Quinn Jia, Wilfredo Villafane

FAA Airport Engineering Division:

Doug Johnson; Greg Cline

SRA International:

Jerry Connelly; Dr. Izydor Kawa; Dr. Qiang Wang; Dr. Yuanguo Chen; Dr. Kairat Tuleubekov, Jeff Stein

Gemini:

Dr. Hao Yin

Consultants:

Dr. Edward Guo; Dr. Maria Lopez; Roy McQueen; Dr. Shelley Stoffels