College Swimming Lineup Game Theory

Import Packages

In [ ]:

```
import numpy as np
import pandas as pd
import os

#import grahpics packages
import seaborn as sns
import matplotlib as mpl
import matplotlib.pyplot as plt

import re
from collections import Counter

plt.style.use('ggplot')

###
# LIST THE INPUT FILES USED!
###
```

In [ ]:

```
os.getcwd()
```

Out[ ]:

```
'c:\\Users\\mdb025\\Documents\\GitHub\\collegeswimming.com-Data-Analysis'
```

In [ ]:

```
# Get the swimmer names to numbers
Swimmer_Names_df = pd.read_csv("SwimmerNames.csv",index_col='swimmer_id')
#print(Swimmer_Names_df)

#Swimmer_Names_dict = dict(zip(Swimmer_Names_df.swimmer_id, Swimmer_Names_df.name))
#Swimmer_Names_dict
```

Read in and convert Swimmer Performance Predictions

These are formatted so that the performance in a relay leg or leadoff is the same for each swimmer (whether in team A, B, C, etc.). For example, it's just the swimmer's best leadoff leg for a relay (FLF50A, FLF50B,...)

TO DO: *Read in raw data and do a sanity/viz check and then add the 3X times after we review the input data*

F = Female

L = Lead, 1=Freestyle, 2=Backstroke, 3=Breaststroke, 4=Butterfly

Unless relay than L,2,3,4 are sequence in relay for medley or L,1 for lead off (1) and leg (2-4) swimmers.

FLFM50A = Female, lead swimmer in 200Y medley realay on A team

In [ ]:

```
# Event Labels Conversion - Don't Currently Use
EventLabelConvertDict = {'F1200Y':'200Y Free', 'F150Y':'50Y Free', 'F1100Y':'100Y Free', 'F4100Y':'100Y Fly', \
        'F2100Y':'100Y Back', 'F2200Y':'200Y Back', 'F1500Y':'500Y Free', 'F5200Y':'200Y IM', 'F3100Y':'100Y Breast', \
        'F4200Y':'200Y Fly','F3200Y':'200Y Breast','F11650Y':'1650Y Free', \
        'FLM50A': '200Y Medley Relay Back A', 'F2M50A': '200Y Medley Relay Breast A', 'F3M50A': '200Y Medley Relay Fly A', 'F4M50A': '200Y Medley Relay Fre
        'FLM50B': '200Y Medley Relay Back B', 'F2M50B': '200Y Medley Relay Breast B', 'F3M50B': '200Y Medley Relay Fly B', 'F4M50B': '200Y Medley Relay Fre
        'FLM50C': '200Y Medley Relay Back C', 'F2M50C': '200Y Medley Relay Breast C', 'F3M50C': '200Y Medley Relay Fly C', 'F4M50C': '200Y Medley Relay Fre
        'FLM50D': '200Y Medley Relay Back D', 'F2M50D': '200Y Medley Relay Breast D', 'F3M50D': '200Y Medley Relay Fly D', 'F4M50D': '200Y Medley Relay Fre
        'FLF50A':'200Y Free Relay Lead A','F1F50A':'200Y Free Relay Leg A', \
        'FLF50B':'200Y Free Relay Lead B','F1F50B':'200Y Free Relay Leg B', \
        'FLF50C':'200Y Free Relay Lead C','F1F50C':'200Y Free Relay Leg C', \
        'FLF50D':'200Y Free Relay Lead D','F1F50D':'200Y Free Relay Leg D'}

print(EventLabelConvertDict)

EventOrder = ['FLM50A', 'F2M50A', 'F3M50A', 'F4M50A',
        'FLM50B', 'F2M50B', 'F3M50B', 'F4M50B', \
        'FLM50C', 'F2M50C', 'F3M50C', 'F4M50C', \
        'FLM50D', 'F2M50D', 'F3M50D', 'F4M50D', \
        'F11650Y', 'F1200Y', 'F2100Y', 'F3100Y', \
        'F4200Y', 'F150Y', 'F1100Y', 'F2200Y', \
        'F3200Y', 'F1500Y', 'F4100Y', 'F5200Y', \
        'FLF50A', 'F1F50A', 'FLF50B', 'F1F50B', \
        'FLF50C', 'F1F50C', 'FLF50D', 'F1F50D']

print(EventOrder)### Order and names for meet scored events
```

```
{'F1200Y': '200Y Free', 'F150Y': '50Y Free', 'F1100Y': '100Y Free', 'F4100Y': '100Y Fly', 'F2100Y': '100Y Back', 'F2200Y': '200Y Back', 'F1500Y': '500Y Fre
e', 'F5200Y': '200Y IM', 'F3100Y': '100Y Breast', 'F4200Y': '200Y Fly', 'F3200Y': '200Y Breast', 'F11650Y': '1650Y Free', 'FLM50A': '200Y Medley Relay Back
A', 'F2M50A': '200Y Medley Relay Breast A', 'F3M50A': '200Y Medley Relay Fly A', 'F4M50A': '200Y Medley Relay Free A', 'FLM50B': '200Y Medley Relay Back
B', 'F2M50B': '200Y Medley Relay Breast B', 'F3M50B': '200Y Medley Relay Fly B', 'F4M50B': '200Y Medley Relay Free B', 'FLM50C': '200Y Medley Relay Back
C', 'F2M50C': '200Y Medley Relay Breast C', 'F3M50C': '200Y Medley Relay Fly C', 'F4M50C': '200Y Medley Relay Free C', 'FLM50D': '200Y Medley Relay Back
D', 'F2M50D': '200Y Medley Relay Breast D', 'F3M50D': '200Y Medley Relay Fly D', 'F4M50D': '200Y Medley Relay Free D', 'FLF50A': '200Y Free Relay Lead A',
'F1F50A': '200Y Free Relay Leg A', 'FLF50B': '200Y Free Relay Lead B', 'F1F50B': '200Y Free Relay Leg B', 'FLF50C': '200Y Free Relay Lead C', 'F1F50C': '20
0Y Free Relay Leg C', 'FLF50D': '200Y Free Relay Lead D', 'F1F50D': '200Y Free Relay Leg D'}
['FLM50A', 'F2M50A', 'F3M50A', 'F4M50A', 'FLM50B', 'F2M50B', 'F3M50B', 'F4M50B', 'FLM50C', 'F2M50C', 'F3M50C', 'F4M50C', 'FLM50D', 'F2M50D', 'F3M50D', 'F4M
50D', 'F11650Y', 'F1200Y', 'F2100Y', 'F3100Y', 'F4200Y', 'F150Y', 'F1100Y', 'F2200Y', 'F3200Y', 'F1500Y', 'F4100Y', 'F5200Y', 'FLF50A', 'F1F50A', 'FLF50B',
'F1F50B', 'FLF50C', 'F1F50C', 'FLF50D', 'F1F50D']
```

Order and names for meet scored events

In [ ]:

```
EventScoreOrder = ['M50', 'F11650Y', 'F1200Y', 'F2100Y', 'F3100Y', \
        'F4200Y', 'F150Y', 'F1100Y', 'F2200Y', \
        'F3200Y', 'F1500Y', 'F4100Y', 'F5200Y', 'F50']

EventScoreLabelConvertDict = {'F1200Y':'200Y Free', 'F150Y':'50Y Free', 'F1100Y':'100Y Free', 'F4100Y':'100Y Fly', \
    'F2100Y':'100Y Back', 'F2200Y':'200Y Back', 'F1500Y':'500Y Free', 'F5200Y':'200Y IM', 'F3100Y':'100Y Breast', \
    'F4200Y':'200Y Fly','F3200Y':'200Y Breast','F11650Y':'1650Y Free', \
    'M50': '200Y Medley Relay', 'F50':'200Y Free Relay'}
```

In [ ]:

```
# Read in team swimmer-event data
```

```
TeamA_Perf_df = pd.read_csv("BucknellPerfwNAs.csv")
TeamB_Perf_df = pd.read_csv("LehighPerfwNAs.csv")
```

In [ ]:

```
TeamA_Perf_df.head()
```

Out[ ]:

	Swimmer	F1200Y	F150Y	F1100Y	F4100Y	F2100Y	F2200Y	F1500Y	F5200Y	F3100Y	...	F3M50D	F4M50D	FLF50A	F1F50A	FLF50B	F1F50B	FLF50C	F1F50C	FLF50D	F1F50I
0	167013	NaN	25.06	54.88	NaN	NaN	NaN	NaN	NaN	NaN	...	NaN	24.92	NaN	24.92	NaN	24.92	NaN	24.92	NaN	24.9
1	214963	NaN	NaN	NaN	NaN	NaN	131.82	NaN	136.12	65.77	...	NaN	24.82	NaN	24.82	NaN	24.82	NaN	24.82	NaN	24.8
2	221480	125.89	24.31	53.15	58.79	NaN	NaN	NaN	NaN	NaN	...	25.41	24.05	24.43	24.05	24.43	24.05	24.43	24.05	24.43	24.0
3	228451	116.94	NaN	53.45	57.58	54.76	117.11	NaN	122.27	69.67	...	NaN	23.25	NaN	23.25	NaN	23.25	NaN	23.25	NaN	23.2
4	233487	112.56	24.81	52.37	55.08	63.05	NaN	NaN	124.53	68.32	...	24.37	23.66	NaN	23.66	NaN	23.66	NaN	23.66	NaN	23.6

5 rows × 37 columns

In [ ]:

```
# Change the index to the unique Swimmer numbers
TeamA_Perf_df.set_index('Swimmer', inplace=True)
TeamB_Perf_df.set_index('Swimmer', inplace=True)

# Reorder the columns based on the order of events in a meet
TeamA_Perf_df = TeamA_Perf_df[EventOrder]
TeamB_Perf_df = TeamB_Perf_df[EventOrder]
```

In [ ]:

```
# Look at mins/max for outliers, errors, and omissions.
TeamA_Perf_df.describe()
```

Out[ ]:

	FLM50A	F2M50A	F3M50A	F4M50A	FLM50B	F2M50B	F3M50B	F4M50B	FLM50C	F2M50C	...	F4100Y	F5200Y	FLF50A	F1F50A	FLF50B	F1F50I
count	7.000000	8.000000	8.000000	21.000000	7.000000	8.000000	8.000000	21.000000	7.000000	8.000000	...	12.000000	14.000000	10.00000	21.000000	10.00000	21.00000
mean	27.467143	31.583750	26.322500	24.559524	27.467143	31.583750	26.322500	24.559524	27.467143	31.583750	...	58.422500	130.167143	24.98900	24.559524	24.98900	24.55952
std	1.392093	1.323426	1.497481	0.942913	1.392093	1.323426	1.497481	0.942913	1.392093	1.323426	...	2.846625	5.444268	0.80626	0.942913	0.80626	0.94291
min	25.380000	29.330000	24.370000	23.170000	25.380000	29.330000	24.370000	23.170000	25.380000	29.330000	...	55.080000	122.270000	23.90000	23.170000	23.90000	23.17000
25%	26.630000	31.092500	25.377500	23.910000	26.630000	31.092500	25.377500	23.910000	26.630000	31.092500	...	56.920000	126.735000	24.45000	23.910000	24.45000	23.91000
50%	27.550000	31.610000	25.790000	24.640000	27.550000	31.610000	25.790000	24.640000	27.550000	31.610000	...	58.165000	130.240000	24.63000	24.640000	24.63000	24.64000
75%	28.225000	32.125000	27.437500	25.130000	28.225000	32.125000	27.437500	25.130000	28.225000	32.125000	...	59.055000	132.735000	25.58000	25.130000	25.58000	25.13000
max	29.630000	33.910000	28.470000	26.640000	29.630000	33.910000	28.470000	26.640000	29.630000	33.910000	...	65.880000	141.870000	26.49000	26.640000	26.49000	26.64000

8 rows × 36 columns

In [ ]:

```
# Look at mins/max for outliers, errors, and omissions.
TeamB_Perf_df.describe()
```

Out[ ]:

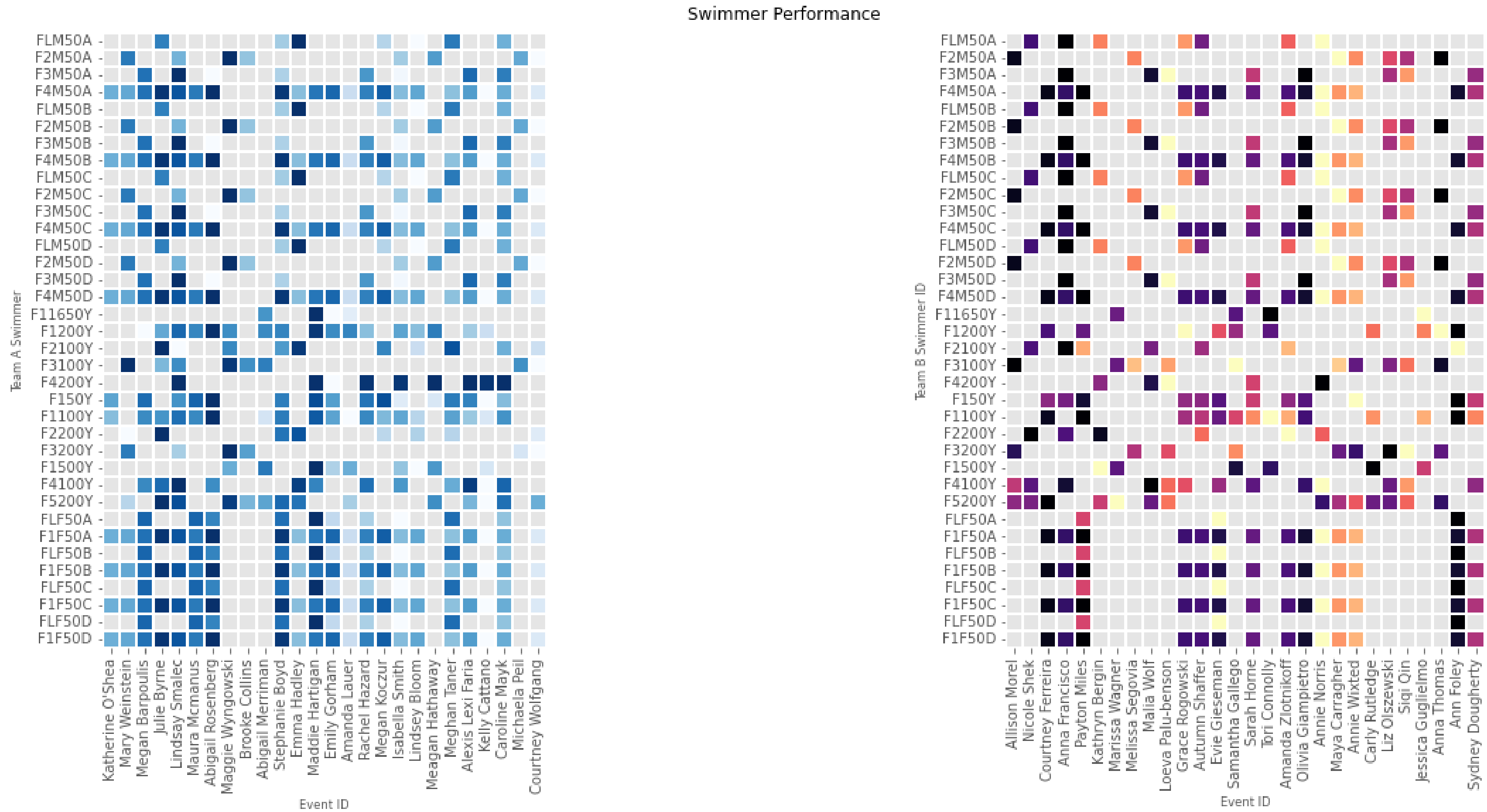
	FLM50A	F2M50A	F3M50A	F4M50A	FLM50B	F2M50B	F3M50B	F4M50B	FLM50C	F2M50C	...	F4100Y	F5200Y	FLF50A	F1F50A	FLF50B	F1F5
count	7.000000	7.000000	8.000000	14.000000	7.000000	7.000000	8.000000	14.000000	7.000000	7.000000	...	13.000000	14.000000	3.000000	14.000000	3.000000	14.000
mean	27.830000	31.134286	26.456250	24.459286	27.830000	31.134286	26.456250	24.459286	27.830000	31.134286	...	58.586923	130.696429	23.700000	24.459286	23.700000	24.459
std	1.252517	0.931788	1.385021	1.746898	1.252517	0.931788	1.385021	1.746898	1.252517	0.931788	...	2.061389	4.089077	0.401497	1.746898	0.401497	1.746
min	25.960000	29.840000	24.890000	22.660000	25.960000	29.840000	24.890000	22.660000	25.960000	29.840000	...	55.470000	123.850000	23.280000	22.660000	23.280000	22.660
25%	26.920000	30.500000	25.170000	23.220000	26.920000	30.500000	25.170000	23.220000	26.920000	30.500000	...	57.460000	128.630000	23.510000	23.220000	23.510000	23.220
50%	28.290000	31.330000	26.570000	23.845000	28.290000	31.330000	26.570000	23.845000	28.290000	31.330000	...	58.380000	129.775000	23.740000	23.845000	23.740000	23.845
75%	28.625000	31.715000	27.130000	25.035000	28.625000	31.715000	27.130000	25.035000	28.625000	31.715000	...	59.910000	133.572500	23.910000	25.035000	23.910000	25.035
max	29.470000	32.340000	28.680000	28.110000	29.470000	32.340000	28.680000	28.110000	29.470000	32.340000	...	62.700000	139.600000	24.080000	28.110000	24.080000	28.110

8 rows × 36 columns

Visualize the predicted time in each event for each swimmer. Heat map.

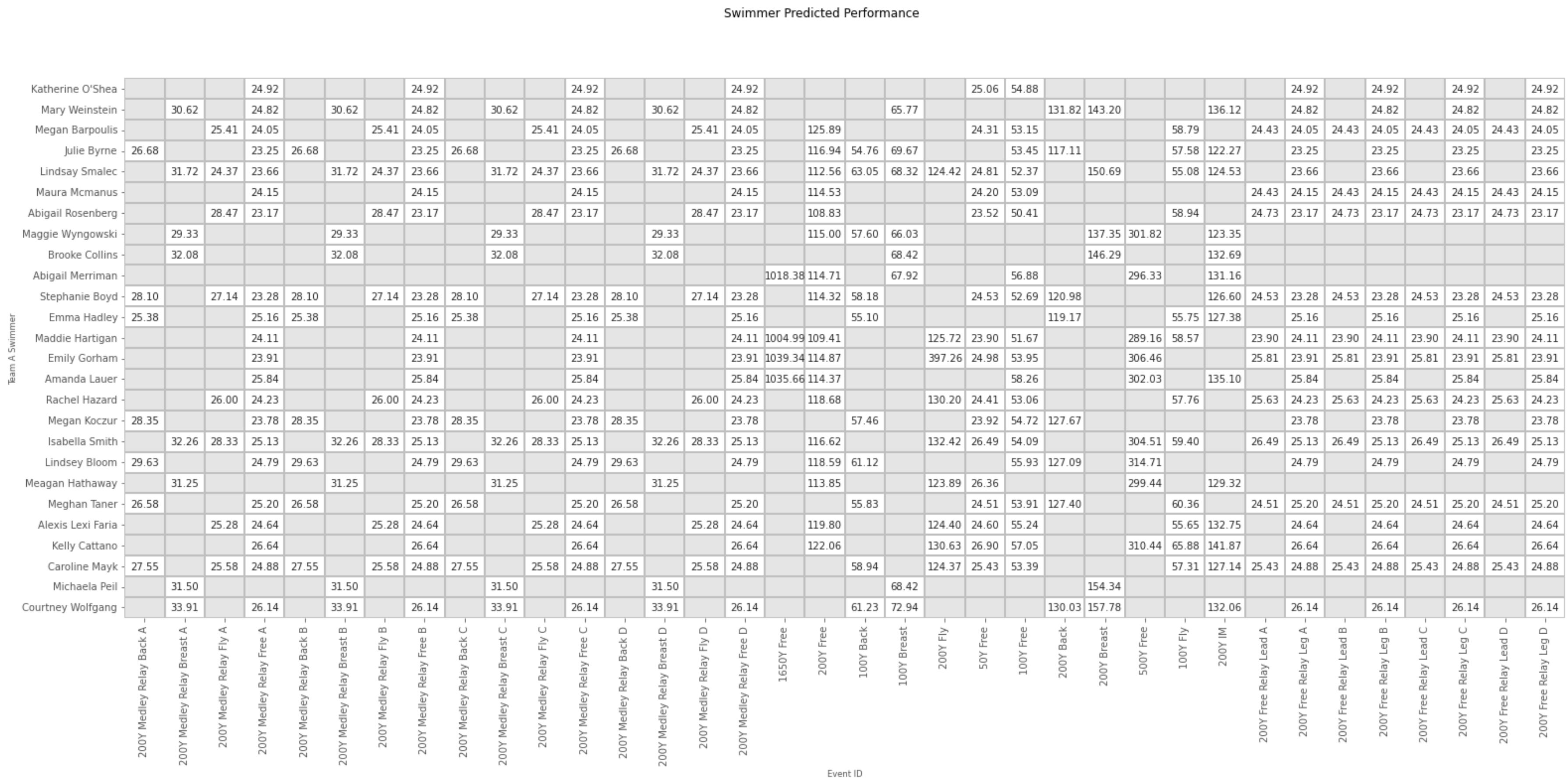
In [ ]:

```
# Displaying performance data frame as a heatmap
# with diverging colourmap as RdYlGn
fig, axs = plt.subplots(1, 2, figsize=(18, 8), constrained_layout=True)

# Make swimmer names the index
TeamA_Perf_Clean_df = pd.merge(left= TeamA_Perf_df, right= Swimmer_Names_df[['name']], how= 'left', left_index= True,right_index=True).set_index('name')
TeamB_Perf_Clean_df = pd.merge(left= TeamB_Perf_df, right= Swimmer_Names_df[['name']], how= 'left', left_index= True,right_index=True).set_index('name')

# Scale the columns to min/max
TeamA_Perf_Clean_df = (TeamA_Perf_Clean_df - TeamA_Perf_Clean_df.min())/(TeamA_Perf_Clean_df.max()-TeamA_Perf_Clean_df.min())
TeamB_Perf_Clean_df = (TeamB_Perf_Clean_df - TeamB_Perf_Clean_df.min())/(TeamB_Perf_Clean_df.max()-TeamB_Perf_Clean_df.min())

sns.heatmap(TeamA_Perf_Clean_df.T, linewidths = 0.30, annot = False, cbar= False, square= True, ax= axs[0], cmap= 'Blues_r')
sns.heatmap(TeamB_Perf_Clean_df.T, linewidths = 0.30, annot = False, cbar= False, square= True, ax= axs[1], cmap= 'magma' )

#clean up the charts
fig.suptitle('Swimmer Performance')
axs[0].set_ylabel('Team A Swimmer',fontsize='small')
axs[1].set_ylabel('Team B Swimmer ID',fontsize='small')

axs[0].set_xlabel('Event ID', fontsize='small')
axs[1].set_xlabel('Event ID', fontsize='small')

plt.show()
```



In [ ]:

```python
from matplotlib.colors import ListedColormap
# Just Bucknell for Dan:
# Displaying performance data frame as a heatmap
fig, axs = plt.subplots(1, 1, figsize=(26, 10), constrained_layout=False)

# Make swimmer names the index
TeamA_Perf_Clean_df = pd.merge(left= TeamA_Perf_df, right= Swimmer_Names_df[['name']], how= 'left', left_index= True,right_index=True).set_index('name')
TeamA_Lineup_Clean_events_df = TeamA_Perf_Clean_df.rename(columns=EventLabelConvertDict)

sns.heatmap(TeamA_Lineup_Clean_events_df, linewidths = 0.10, annot = True, fmt= '.2f', cbar= False, square= False, ax= axs, cmap = ListedColormap(['white']

#clean up the charts
fig.suptitle('Swimmer Predicted Performance')
axs.set_ylabel('Team A Swimmer',fontsize='small')
axs.set_xlabel('Event ID', fontsize='small')

plt.show()
```



In [ ]:

```python
# Write performance to Excel for Dan
TeamA_Lineup_Clean_events_df.to_excel('Bucknell_Predicted_Performance.xlsx')
```

Now compute the BigM values and add to the performance dataFrame

In [ ]:

```python
# define the BigM value for each event and replace the NaNs with the BigM value
BigM = dict()
TeamA_Perf_wM_df = TeamA_Perf_df.copy()
TeamB_Perf_wM_df = TeamB_Perf_df.copy()

for ev in EventOrder:

    #Big M is defined at 1.5x the largest observed value in the event
    temp = 4*max(TeamA_Perf_df[ev].max(),TeamB_Perf_df[ev].max())
    BigM[ev] = temp

    TeamA_Perf_wM_df[ev] = TeamA_Perf_df[ev].fillna(temp)
    TeamB_Perf_wM_df[ev] = TeamB_Perf_df[ev].fillna(temp)
```

```python
# Create the BigM for the relay events from the four legs
BigM['M50'] = BigM['FLF50A'] + 3*BigM['F1F50A']
BigM['F50'] = BigM['FLM50A'] + BigM['F2M50A'] + BigM['F3M50A'] + BigM['F4M50A']

# Display the BigM values as a dataframe
pd.DataFrame.from_dict(BigM, orient='index',columns= ['BigM'])
```

Out[ ]:

	BigM
FLM50A	118.52
F2M50A	135.64
F3M50A	114.72
F4M50A	112.44
FLM50B	118.52
F2M50B	135.64
F3M50B	114.72
F4M50B	112.44
FLM50C	118.52
F2M50C	135.64
F3M50C	114.72
F4M50C	112.44
FLM50D	118.52
F2M50D	135.64
F3M50D	114.72
F4M50D	112.44
F11650Y	4396.20
F1200Y	503.56
F2100Y	252.20
F3100Y	291.76
F4200Y	1589.04
F150Y	107.60
F1100Y	233.04
F2200Y	527.28
F3200Y	631.12
F1500Y	1259.96
F4100Y	263.52

	BigM
F5200Y	567.48
FLF50A	105.96
F1F50A	112.44
FLF50B	105.96
F1F50B	112.44
FLF50C	105.96
F1F50C	112.44
FLF50D	105.96
F1F50D	112.44
M50	443.28
F50	481.32

In [ ]:

```
TeamA_Perf_wM_df.describe()
```

Out[ ]:

	FLM50A	F2M50A	F3M50A	F4M50A	FLM50B	F2M50B	F3M50B	F4M50B	FLM50C	F2M50C	...	F4100Y	F5200Y	FLF50A	F1F50A	F
count	26.000000	26.000000	26.000000	26.000000	26.000000	26.000000	26.000000	26.000000	26.000000	26.000000	...	26.000000	26.000000	26.000000	26.000000	26.(
mean	94.005769	103.622692	87.520769	41.459615	94.005769	103.622692	87.520769	41.459615	94.005769	103.622692	...	168.859615	332.003846	74.817308	41.459615	74.8
std	41.192889	48.982069	41.614367	35.330854	41.192889	48.982069	41.614367	35.330854	41.192889	48.982069	...	104.286845	222.360636	40.175779	35.330854	40.1
min	25.380000	29.330000	24.370000	23.170000	25.380000	29.330000	24.370000	23.170000	25.380000	29.330000	...	55.080000	122.270000	23.900000	23.170000	23.9
25%	51.852500	32.672500	28.365000	24.065000	51.852500	32.672500	28.365000	24.065000	51.852500	32.672500	...	58.625000	129.780000	25.480000	24.065000	25.4
50%	118.520000	135.640000	114.720000	24.850000	118.520000	135.640000	114.720000	24.850000	118.520000	135.640000	...	263.520000	138.995000	105.960000	24.850000	105.9
75%	118.520000	135.640000	114.720000	26.065000	118.520000	135.640000	114.720000	26.065000	118.520000	135.640000	...	263.520000	567.480000	105.960000	26.065000	105.9
max	118.520000	135.640000	114.720000	112.440000	118.520000	135.640000	114.720000	112.440000	118.520000	135.640000	...	263.520000	567.480000	105.960000	112.440000	105.9

8 rows × 36 columns

In [ ]:

```
TeamB_Perf_wM_df.describe()
```

Out[ ]:

	FLM50A	F2M50A	F3M50A	F4M50A	FLM50B	F2M50B	F3M50B	F4M50B	FLM50C	F2M50C	...	F4100Y	F5200Y	FLF50A	F1F50A	FLF5
count	28.00000	28.000000	28.000000	28.000000	28.00000	28.000000	28.000000	28.000000	28.00000	28.000000	...	28.000000	28.000000	28.000000	28.000000	28.000
mean	95.84750	109.513571	89.501786	68.449643	95.84750	109.513571	89.501786	68.449643	95.84750	109.513571	...	168.372500	349.088214	97.146429	68.449643	97.146
std	39.99489	46.084782	40.611306	44.813983	39.99489	46.084782	40.611306	44.813983	39.99489	46.084782	...	104.089356	222.417407	25.909695	44.813983	25.909

	FLM50A	F2M50A	F3M50A	F4M50A	FLM50B	F2M50B	F3M50B	F4M50B	FLM50C	F2M50C	...	F4100Y	F5200Y	FLF50A	F1F50A	FLF!
min	25.96000	29.840000	24.890000	22.660000	25.96000	29.840000	24.890000	22.660000	25.96000	29.840000	...	55.470000	123.850000	23.280000	22.660000	23.280
25%	96.25750	109.815000	28.480000	23.877500	96.25750	109.815000	28.480000	23.877500	96.25750	109.815000	...	58.545000	129.972500	105.960000	23.877500	105.960
50%	118.52000	135.640000	114.720000	70.275000	118.52000	135.640000	114.720000	70.275000	118.52000	135.640000	...	263.520000	353.540000	105.960000	70.275000	105.960
75%	118.52000	135.640000	114.720000	112.440000	118.52000	135.640000	114.720000	112.440000	118.52000	135.640000	...	263.520000	567.480000	105.960000	112.440000	105.960
max	118.52000	135.640000	114.720000	112.440000	118.52000	135.640000	114.720000	112.440000	118.52000	135.640000	...	263.520000	567.480000	105.960000	112.440000	105.960

8 rows × 36 columns

Read in initial lineups for both teams and put in a list. We'll create improvedd lineups later.

In [ ]:

```
# Global
TOTAL_LINEUPS = 4

# Initialize lists of lineups for teams A and B
TeamA_Lineup_df = [None] * TOTAL_LINEUPS
TeamB_Lineup_df = [None] * TOTAL_LINEUPS

# Read the initial lineups into a list as the first (base) lineup
TeamA_Lineup_df[0] = pd.read_csv("Bucknell_1_Lineup.csv",index_col='Swimmer')
TeamB_Lineup_df[0] = pd.read_csv("Lehigh_1_Lineup.csv",index_col='Swimmer')

#TeamA_Lineup_df = []
#TeamA_Lineup_df.append(pd.read_csv("Bucknell_1_Lineup.csv",index_col='Swimmer'))

#TeamB_Lineup_df = []
#TeamB_Lineup_df.append(pd.read_csv("Lehigh_1_Lineup.csv",index_col='Swimmer'))

# What are the line up events we'll need to assign later?
# We won't really need the D relay team, but keep for consistency
Lineup_Events = tuple(TeamA_Lineup_df[0].columns.tolist())

# Order the colummns to the meet event order
TeamA_Lineup_df[0] = TeamA_Lineup_df[0][EventOrder]
TeamB_Lineup_df[0] = TeamB_Lineup_df[0][EventOrder]

print(Lineup_Events)
```

```
('F1200Y', 'F150Y', 'F1100Y', 'F4100Y', 'F2100Y', 'F2200Y', 'F1500Y', 'F5200Y', 'F3100Y', 'F4200Y', 'F3200Y', 'F11650Y', 'FLM50A', 'F2M50A', 'F3M50A', 'F4M
50A', 'FLM50B', 'F2M50B', 'F3M50B', 'F4M50B', 'FLM50C', 'F2M50C', 'F3M50C', 'F4M50C', 'FLM50D', 'F2M50D', 'F3M50D', 'F4M50D', 'FLF50A', 'F1F50A', 'FLF50B',
'F1F50B', 'FLF50C', 'F1F50C', 'FLF50D', 'F1F50D')
```

The base meet did NOT swim a 1650Y Free (F11650Y) or 200Y Free Relay, they swam a 1000Y Free (F11000Y) and 400Y Free Relay instead, make some adjustments to the lineups

In [ ]:

```
# Swimmers were accidentally put in 100Y that actually swam the 1000Y Free from Data Scrape
TeamA_Lineup_df[0].at[260001,'F1100Y'] = 0
```

```
TeamA_Lineup_df[0].at[402879,'F1100Y'] = 0

TeamB_Lineup_df[0].at[330114,'F1100Y'] = 0
TeamB_Lineup_df[0].at[696579,'F1100Y'] = 0
```

In [ ]:

```
# # Add the 1650 Swimmers from the meet that swam the 1000Y Free instead
TeamA_Lineup_df[0].at[330237,'F11650Y'] = 1
TeamA_Lineup_df[0].at[260001,'F11650Y'] = 1
TeamA_Lineup_df[0].at[356813,'F11650Y'] = 1
TeamA_Lineup_df[0].at[330324,'F11650Y'] = 1

TeamB_Lineup_df[0].at[404163,'F11650Y'] = 1
TeamB_Lineup_df[0].at[342505,'F11650Y'] = 1
TeamB_Lineup_df[0].at[271442,'F11650Y'] = 1
TeamB_Lineup_df[0].at[422229,'F11650Y'] = 1
```

In [ ]:

```
# Add the 200 Free Relay from the 400 Free Relay for TEAM A

TeamA_Lineup_df[0].at[329465,'FLF50A'] = 1
TeamA_Lineup_df[0].at[265562,'F1F50A'] = 1
TeamA_Lineup_df[0].at[233650,'F1F50A'] = 1
TeamA_Lineup_df[0].at[342607,'F1F50A'] = 1

TeamA_Lineup_df[0].at[221480,'FLF50B'] = 1
TeamA_Lineup_df[0].at[342611,'F1F50B'] = 1
TeamA_Lineup_df[0].at[382148,'F1F50B'] = 1
TeamA_Lineup_df[0].at[395502,'F1F50B'] = 1

TeamA_Lineup_df[0].at[260001,'FLF50C'] = 1
TeamA_Lineup_df[0].at[356813,'F1F50C'] = 1
TeamA_Lineup_df[0].at[347298,'F1F50C'] = 1
TeamA_Lineup_df[0].at[344005,'F1F50C'] = 1
```

In [ ]:

```
# Add the 200 Free Relay from the 400 Free Relay Roster for TEAM B

TeamB_Lineup_df[0].at[494957,'FLF50A'] = 1
TeamB_Lineup_df[0].at[233836,'F1F50A'] = 1
TeamB_Lineup_df[0].at[342918,'F1F50A'] = 1
TeamB_Lineup_df[0].at[213253,'F1F50A'] = 1

TeamB_Lineup_df[0].at[330114,'FLF50B'] = 1
TeamB_Lineup_df[0].at[282290,'F1F50B'] = 1
TeamB_Lineup_df[0].at[323285,'F1F50B'] = 1
TeamB_Lineup_df[0].at[330349,'F1F50B'] = 1

TeamB_Lineup_df[0].at[696579,'FLF50C'] = 1
TeamB_Lineup_df[0].at[273646,'F1F50C'] = 1
TeamB_Lineup_df[0].at[291023,'F1F50C'] = 1
TeamB_Lineup_df[0].at[404163,'F1F50C'] = 1
```

In [ ]:

```
# Clean up values just in case
```

```
TeamA_Lineup_df[0] = TeamA_Lineup_df[0][TeamA_Lineup_df[0].columns].astype('int8')
TeamB_Lineup_df[0] = TeamB_Lineup_df[0][TeamB_Lineup_df[0].columns].astype('int8')
```

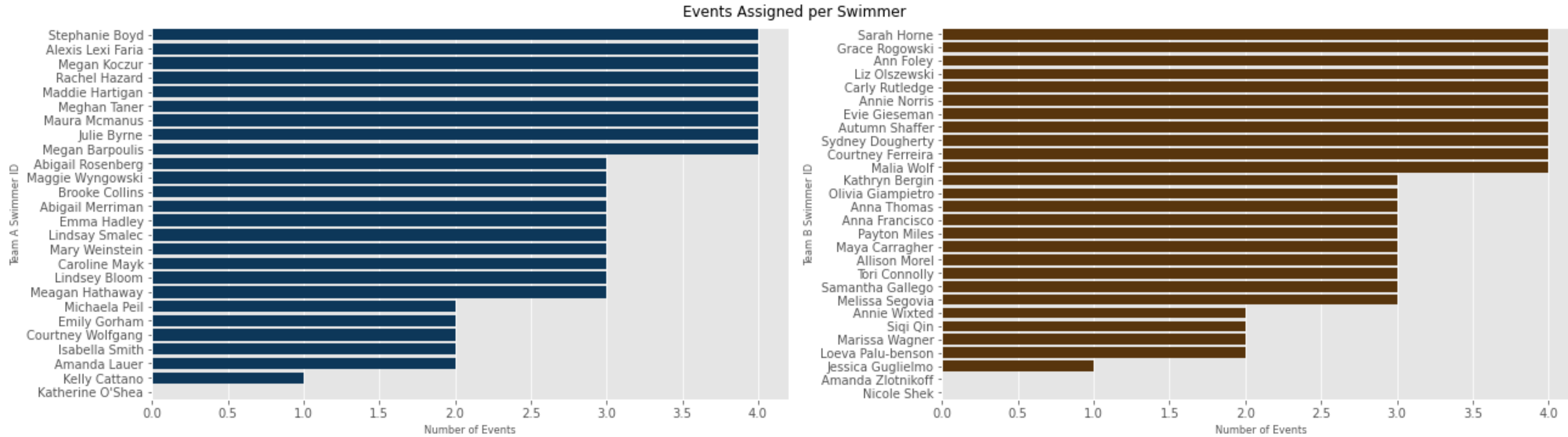
EDA on the Base Team Lineups

In [ ]:

```
# Some colors for consistency
TeamA_blue = (0,.22,.4)
TeamA_orange = (0.9,0.46,0.13)
TeamB_yellow = (1,0.82,0.309)
TeamB_brown = (0.396, 0.211,0)

TeamA_colors = [TeamA_orange, TeamA_blue]
TeamB_colors = [TeamB_yellow, TeamB_brown]
```

In [ ]:

```
# How many Events for each swimmer?

fig, axs = plt.subplots(1, 2, figsize=(18, 5), constrained_layout=True)

# Team A
TeamA_TotEventsPerAth = TeamA_Lineup_df[0].sum(axis=1).sort_values(ascending=False).to_frame().rename(columns={0: "tot_events"})
TeamA_TotEventsPerAth = pd.merge(left= TeamA_TotEventsPerAth, right= Swimmer_Names_df[['name']], how= 'left', left_index= True,right_index=True)
sns.barplot(y=TeamA_TotEventsPerAth.name, x=TeamA_TotEventsPerAth.tot_events, color= TeamA_blue,ax=axs[0])

# Team B
TeamB_TotEventsPerAth = TeamB_Lineup_df[0].sum(axis=1).sort_values(ascending=False).to_frame().rename(columns={0: "tot_events"})
TeamB_TotEventsPerAth = pd.merge(left= TeamB_TotEventsPerAth, right= Swimmer_Names_df[['name']], how= 'left', left_index= True,right_index=True)
sns.barplot(y=TeamB_TotEventsPerAth.name, x=TeamB_TotEventsPerAth.tot_events, color= TeamB_brown,ax=axs[1])

#clean up the charts
fig.suptitle('Events Assigned per Swimmer')
axs[0].set_ylabel('Team A Swimmer ID',fontsize='small')
axs[1].set_ylabel('Team B Swimmer ID',fontsize='small')

#for ax in axs:
#    ax.set_ylim([0, 4.2])
axs[0].set_xlabel('Number of Events', fontsize='small')
axs[1].set_xlabel('Number of Events', fontsize='small')
plt.show()
```

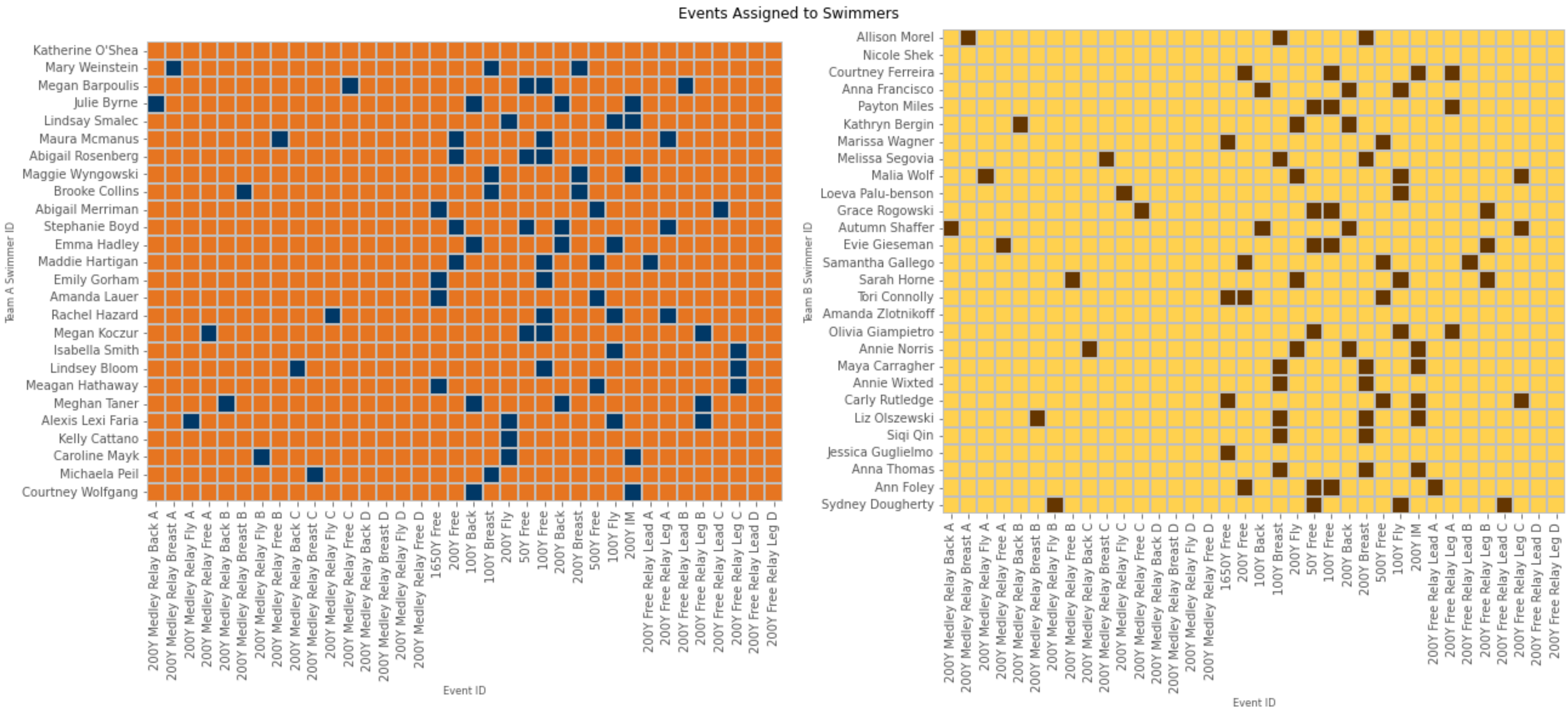


We can see that some swimmers were put in an as many as four swimming events at this meet. The focus of on our analysis is on assignments that will likely score in the meet. The coach can make adjustments to add athletes they want in events, but likely won't score.

In [ ]:

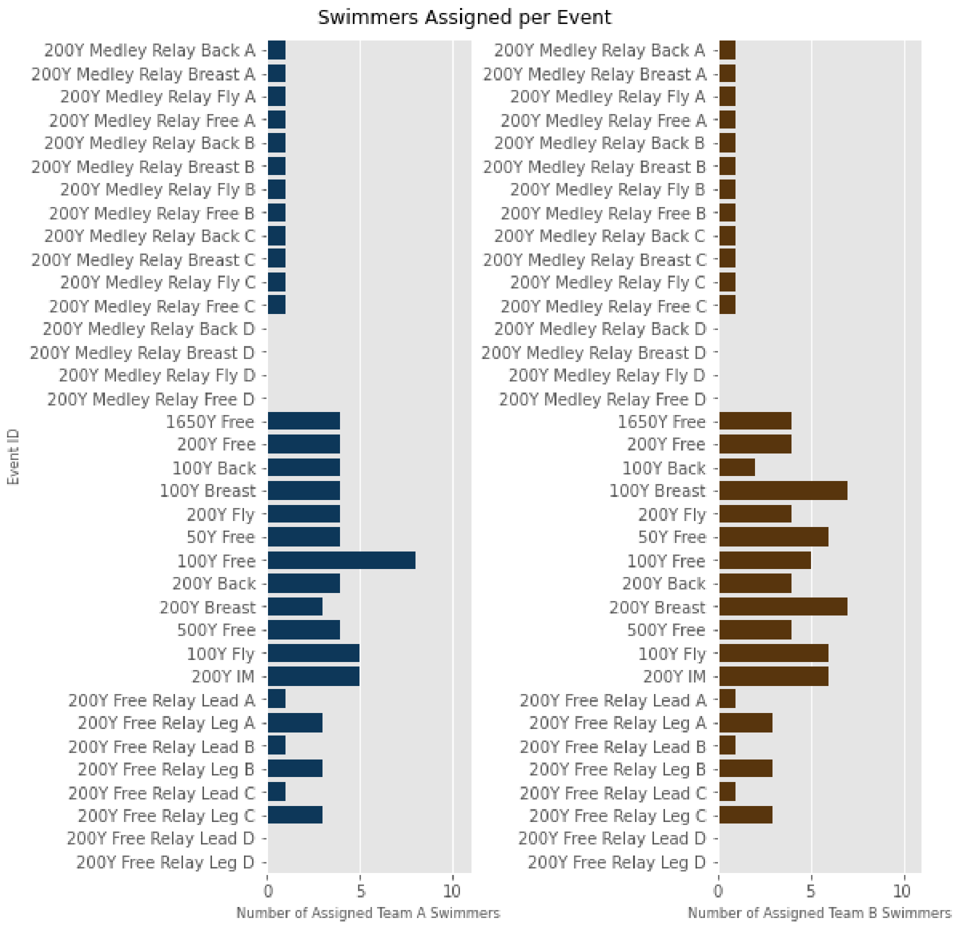
```
# Displaying dataframe as an heatmap
# with diverging colourmap as RdYlGn
fig, axs = plt.subplots(1, 2, figsize=(18, 8), constrained_layout=True)

# Make swimmer names the index
TeamA_Lineup_Clean_df = pd.merge(left= TeamA_Lineup_df[0], right= Swimmer_Names_df[['name']], how= 'left', left_index= True,right_index=True).set_index('na
TeamB_Lineup_Clean_df = pd.merge(left= TeamB_Lineup_df[0], right= Swimmer_Names_df[['name']], how= 'left', left_index= True,right_index=True).set_index('na

TeamA_Lineup_Clean_df = TeamA_Lineup_Clean_df.rename(columns=EventLabelConvertDict)
TeamB_Lineup_Clean_df = TeamB_Lineup_Clean_df.rename(columns=EventLabelConvertDict)


sns.heatmap(TeamA_Lineup_Clean_df, linewidths = 0.1, annot = False, cbar= False, square= True, ax= axs[0], cmap= TeamA_colors, linecolor='0.75')
sns.heatmap(TeamB_Lineup_Clean_df, linewidths = 0.1, annot = False, cbar= False, square= True, ax= axs[1], cmap= TeamB_colors, linecolor='0.75')

#clean up the charts
fig.suptitle('Events Assigned to Swimmers')
axs[0].set_ylabel('Team A Swimmer ID',fontsize='small')
axs[1].set_ylabel('Team B Swimmer ID',fontsize='small')

axs[0].set_xlabel('Event ID', fontsize='small')
axs[1].set_xlabel('Event ID', fontsize='small')

# colorbar = axs[0].collections[0].colorbar
# colorbar.set_ticks([.25,.75])
# colorbar.set_ticklabels(['Not Assigned','Assigned'])

# colorbar2 = axs[1].collections[0].colorbar
# colorbar2.set_ticks([.25,.75])
# colorbar2.set_ticklabels(['Not Assigned','Assigned'])
```

```python
plt.show()
```



In [ ]:

```python
# How many athletes for each event?
fig, axs = plt.subplots(1, 2, figsize=(8, 8), sharey=False, constrained_layout=True)

# Team A
TeamA = TeamA_Lineup_df[0].rename(columns=EventLabelConvertDict).sum(axis=0)
sns.barplot(y=TeamA.index, x=TeamA.values, color= TeamA_blue,ax=axs[0], ci=None)

#Team B
TeamB = TeamB_Lineup_df[0].rename(columns=EventLabelConvertDict).sum(axis=0)
sns.barplot(y=TeamB.index, x=TeamB.values, color= TeamB_brown, ax=axs[1], ci=None)

#clean up the charts
fig.suptitle('Swimmers Assigned per Event')
axs[0].set_ylabel('Event ID',fontsize='small')

for ax in axs:
    ax.set_xlim([0, 11])
axs[0].set_xlabel('Number of Assigned Team A Swimmers', fontsize='small')
axs[1].set_xlabel('Number of Assigned Team B Swimmers', fontsize='small')
plt.show()
```



Set the scoring rules for the meet

In [ ]:

```
# Point Values for each place in an event category. Format: {# of Lanes: [1st place, 2nd place,... nth place]}
INDIVIDUAL_POINTS = {"Six Lane": [9, 4, 3, 2, 1, 0], "Five Lane": [5, 3, 1, 0]}
RELAY_POINTS = {"Six Lane": [11, 4, 2], "Five Lane": [7, 0]}
# Limit for number of people who can score per team in each event type. Format: {# of Lanes: [Individual, Relay]}
SCORER_LIMIT = {"Six Lane": [3,2], "Five Lane": [2,1]}
```

Determine the Expected Score for Team A and Team B when using a given set of performances AND lineups

In [ ]:

```
def calculate_pred_score(perf_team_a, line_team_a, perf_team_b, line_team_b, scoring_method="Six Lane"):
    """
    returns the predicted score of team A for a swimming meet
    :param perf_team_a: Pandas dataframe of predicted performances for a given team A's swimmers
    :param line_team_a: Pandas Dataframe of a given lineup for a team A
    :param perf_team_b: Pandas dataframe of predicted performances for a given team B's swimmers
```

```python
    :param line_team_b: Pandas Dataframe of a given lineup for a team B
    :param scoring_method: used to determine how points are allocated
    :return: pred_score: Integer value of team A's predicted
    """

    # create predicted performance matrices that only contain values for swimmers in the lineup
    lineup_scores_a = perf_team_a[line_team_a == 1]
    lineup_scores_b = perf_team_b[line_team_b == 1]

    # Team scores are integer values, initialize them at 0
    score_a = score_b = 0

    # Find times for all relay events and put them together in one dictionary
    event_list = lineup_scores_a.columns.tolist()
    # look for relay events. the lookup is performed by finding the leadoff
    r = re.compile(".L[MF].+")
    relay_list = list(filter(r.match, event_list))
    #print(relay_list)
    relay_event_results = dict()
    for value in relay_list:
        #find out what type of relay value is and make list of legs in relay
        if value[2] == "F":
            # relay is a freestyle relay, so there are two types of legs
            legs = [value, value[:1]+"1"+value[2:]]
        elif value[2] == "M":
            # relay is medley relay, so there are four different legs
            legs = [value, value[:1] + "2" + value[2:], value[:1] + "3" + value[2:], value[:1] + "4" + value[2:]]
        # get sum of legs in relay for full relay time.
        time_a = lineup_scores_a[legs].sum().sum()
        time_b = lineup_scores_b[legs].sum().sum()
        # if event is in dictionary, update data, if not then append it
        if value[2:-1] in relay_event_results:
            if time_a != 0:
                relay_event_results[value[2:-1]][0].append(time_a)
            if time_b != 0:
                relay_event_results[value[2:-1]][1].append(time_b)
        else:
            relay_event_results[value[2:-1]] = [[time_a],[time_b]]
            if time_a == 0:
                relay_event_results[value[2:-1]][0].pop()
            if time_b == 0:
                relay_event_results[value[2:-1]][1].pop()

    # dataframe to keep event scores
    eventScore_df = pd.DataFrame(columns = ['event','team','score'])

    # score the relays
    for event in relay_event_results:
        # get results for each team by event
        results_a = relay_event_results[event][0]
        #print("results for relay event ", event, " are ", results_a)
        results_b = relay_event_results[event][1]
        temp_a, temp_b = score_event(results_a, results_b, RELAY_POINTS[scoring_method], SCORER_LIMIT[scoring_method][1])
        score_a += temp_a
        score_b += temp_b
        eventScore_df = eventScore_df.append({'event' : event, 'team': 'Team A', 'score' : temp_a},ignore_index= True)
```

```python
        eventScore_df = eventScore_df.append({'event' : event, 'team': 'Team B', 'score' : temp_b},ignore_index= True)
        #print("Event ", event, ":")
        #print("\tBucknell: ",temp_a,", Lehigh: ",temp_b)
    # score individual events, which we identify in the line below
    individual_events = list(filter(lambda x: x[2] not in "MF", event_list))
    for column_name in individual_events:
        results_a = lineup_scores_a[column_name][lineup_scores_a[column_name].notna()].tolist()
        #print("results for event ", column_name, " are ", results_a)
        results_b = lineup_scores_b[column_name][lineup_scores_b[column_name].notna()].tolist()
        temp_a, temp_b = score_event(results_a, results_b, INDIVIDUAL_POINTS[scoring_method],
                                     SCORER_LIMIT[scoring_method][0])
        # cannot add to two values at same time, so we have to assign points to temp values and then add those to score
        score_a += temp_a
        score_b += temp_b
        #print("Event ", column_name, ":")
        #print("\tBucknell: ",temp_a,", Lehigh: ",temp_b)
        eventScore_df = eventScore_df.append({'event' : column_name, 'team': 'Team A', 'score' : temp_a},ignore_index= True)
        eventScore_df = eventScore_df.append({'event' : column_name, 'team': 'Team B', 'score' : temp_b},ignore_index= True)
    return score_a, score_b, eventScore_df
```

In [ ]:

```python
def score_event(results_a, results_b, places, scoring_limit):
    """
    assigns points to groups based on who has the smallest score/time.
    :param results_a: list of recorded times for team a
    :param results_b: list of recorded times for team b
    :param places: list of point values awarded for first, second, etc place
    :param scoring_limit: the maximum number of swimmers per team that can score in the event
    :return: scores of team a and b
    """
    score_a = score_b = place_counter = 0
    all_times = results_a + results_b  # make a list of all times scored in the event
    all_times.sort()  # sort the list in ascending order
    a_scorers = b_scorers = 0
    results_dict = dict(Counter(all_times))  # convert list to dictionary. key is time, value is frequency of time

    for i in results_dict:
        if place_counter >= len(places):  # When there are no more points to award for the event break the loop
            break

        if results_dict[i] == 1:  # only one instance of the given time in either list (i.e. not a tie)
            if i in results_a:
                if a_scorers <= scoring_limit:
                    score_a = score_a + places[place_counter]
            else:
                if b_scorers <= scoring_limit:
                    score_b = score_b + places[place_counter]

        else:  # this signifies a tie, results_dict[i] > 1
            # split points awarded among all tied players
            points_per_player = sum(places[place_counter: place_counter + results_dict[i]]) / results_dict[i]
            if a_scorers <= scoring_limit:
                score_a += results_a.count(i) * points_per_player
            if b_scorers <= scoring_limit:
                score_b += results_b.count(i) * points_per_player
```

```
        a_scorers += results_a.count(i)
        b_scorers += results_b.count(i)
        place_counter = place_counter + results_dict[i]

    return score_a, score_b
```

Return Data to project who should win which events based on lineups and predicted performances and show on chart

19 total points for indiv and 17 for relay

12 indiv and 2 relay = 262 total points

In [ ]:

```
score_A,score_B,eventScore_df = calculate_pred_score(TeamA_Perf_wM_df, TeamA_Lineup_df[0], \
    TeamB_Perf_wM_df, TeamB_Lineup_df[0], scoring_method="Six Lane")

print("Projected scores: \nTeam A: ",score_A,"\nTeam B: ",score_B)
```

```
Projected scores:
Team A:  137.0
Team B:  125.0
```

In the actual 1/26/2019 Team A (Bucknell) won 161-137 (including diving events).

In just swimming events the actual score was 137-125 as we just predicted.

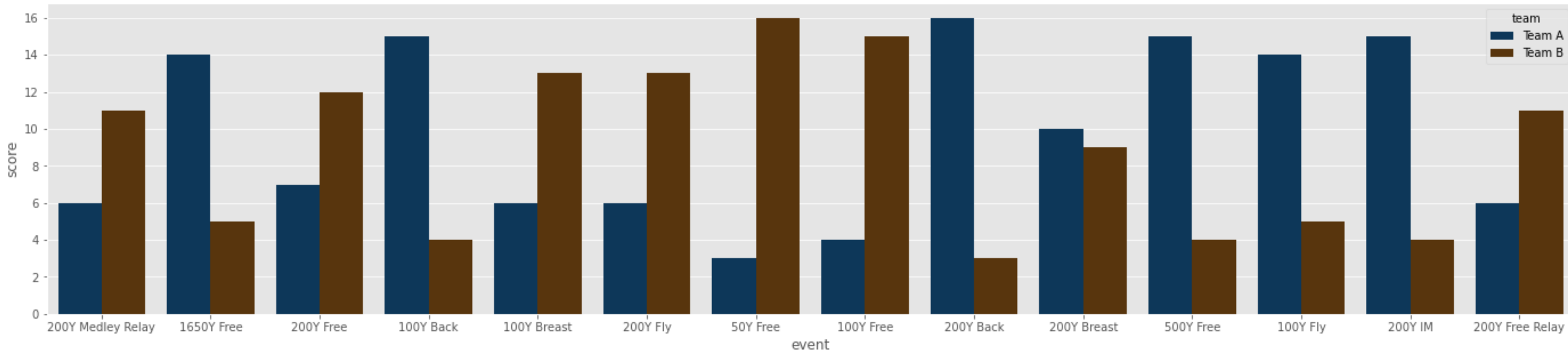
Function to Display bar chart of team scores in events:

In [ ]:

```
def ChartScore(EventScores, TeamAcolor, TeamBcolor, FigSize_h, FigSize_l):
    """
    :param Scores: A dataframe of the two two scores for each event
    :param TeamLineup: Dataframe of team lineup. Index is swimmer_id and columns are events
    :param TeamAColor: Matplotlib color for Team A columns, e.g. (0,.22,.4)
    :param TeamBColor: Matplotlib color for Team B columns, e.g. (0,.22,.4)
    :param FigSize_h, FigSize_l: figur height and width in inches.

    #returns plot of given lineup

    """
    # Initialize the matplotlib figure
    f, ax = plt.subplots(figsize=(FigSize_h, FigSize_l))

    # Set event field as category, reorder to meet order, and rename to user-friendly names
    Scores = EventScores.copy()
    Scores.event = Scores.event.astype('category')
    Scores.event = Scores.event.cat.reorder_categories(EventScoreOrder)
    Scores.event = Scores.event.cat.rename_categories(EventScoreLabelConvertDict)

    sns.barplot(x="event", y="score", hue='team', data=Scores, palette=[TeamAcolor,TeamBcolor], ci=None);

    return
```

In [ ]:

```
ChartScore(eventScore_df, TeamA_blue, TeamB_brown,24,5)
```



For a given opponent lineup, generate the top three sorted scores in each event. Then add ghost max scores for places 4, 5

What should max time and Big_M be for each event?

In [ ]:

```
def create_opptime_dict(perf_team_a, line_team_a, Big_M):
    """
    MDB function Addition

    returns the predicted opposition times for a given line up (scenario)
    :param perf_team_a: Pandas dataframe of predicted performances for a given team A's swimmers
    :param line_team_a: Pandas Dataframe of a given lineup for a team A
    :param Big_M: A dictionary of the Big M values for each scoring event AND the relay legs

    :return: opptime_team_a: dictionary of team A's top three times in each event
    """
    # We're going to reduce all the opptimes by 0.001 to avoid ties by MeetOpt the precision for the input data is only to
    # t0 0.01, so this should affect points, but will avoid ties with how MeetOpt works. For more precise input data,
    # this may not be necessary, but it should be at least one place of precision more than the input data.

    tiebreak = 0.001

    # create predicted performance matrices that only contain values for swimmers in the lineup
    lineup_scores_a = perf_team_a[line_team_a == 1]

    # Find times for all relay events and put them together in one dictionary
    event_list = lineup_scores_a.columns.tolist()
    # look for relay events. the lookup is performed by finding the leadoff
    r = re.compile(".L[MF].+")
    relay_list = list(filter(r.match, event_list))
    relay_event_results = dict()
```

```python
#print(relay_list)

for value in relay_list:
    #find out what type of relay value is and make list of legs in relay
    if value[2] == "F":
        # relay is a freestyle relay, so there are two types of legs
        legs = [value, value[:1]+"1"+value[2:]]
    elif value[2] == "M":
        # relay is medley relay, so there are four different legs
        legs = [value, value[:1] + "2" + value[2:], value[:1] + "3" + value[2:], value[:1] + "4" + value[2:]]
    # get sum of legs in relay for full relay time.
    time_a = lineup_scores_a[legs].sum().sum()
    # if event is in dictionary, update data, if not then append it
    if value[2:-1] in relay_event_results:
        if time_a != 0:
            relay_event_results[value[2:-1]][0].append(time_a)
    else:
        relay_event_results[value[2:-1]] = [[time_a]]
        if time_a == 0:
            relay_event_results[value[2:-1]][0].pop()

# create opptime_team_a sorted dictionary of predicted opponent times by event
# number of places to score the events (likely three for a dual meet) ...SHOULD NOT HARD CODE THIS!
places = [1, 2, 3, 4, 5]

opptime_team_a = {}
for p in places:
    opptime_team_a[p] = {}

relay_events = list()
for event in relay_event_results:
    # get results for each team by event
    results_a = relay_event_results[event][0]
    results_a.sort()
    # set the opptime dictionary to sorted time of opp pred times
    for p in places:
        if p <= len(results_a):
            opptime_team_a[p][event] = results_a[p-1] - tiebreak
        else:
            # Make the filler event time a little smaller for the opposing team (tie goes to home)
            opptime_team_a[p][event] = Big_M[event] - tiebreak

    # add the event to the list of events
    relay_events.append(event)


# score individual events, which we identify in the line below
individual_events = list(filter(lambda x: x[2] not in "MF", event_list))
for column_name in individual_events:
    event = column_name
    results_a = lineup_scores_a[event][lineup_scores_a[event].notna()].tolist()
    results_a.sort()

    for p in places:
        if p <= len(results_a):
            opptime_team_a[p][event] = results_a[p-1] - tiebreak
```

```
        else:
            # Make the filler event time a little larger for the opposing team (tie goes to home)
            opptime_team_a[p][event] = Big_M[event] - tiebreak

    return opptime_team_a
```

Get opptime for Team B's lineup(s)

In [ ]:

```
# opponents times needs to be in lineup (or scenario), opponent rank (1,2,3,4), then the name of the scored event
TeamB_lineupNums = 1
opptime_TeamB_dict = dict()
for i in range(TeamB_lineupNums):
    opptime_TeamB_dict[i+1] = create_opptime_dict(TeamB_Perf_wM_df, TeamB_Lineup_df[i], BigM)

opptime_TeamB_dict[1][4]['M50']
```

Out[ ]:

```
443.279
```

OK, now we have performance data for Team A (Bucknell) and opptime prediction for Team B (Lehigh) with the given lineups.

Compute a (possibly) better lineup for Team A (Bucknell) vs. this lineup

Get the Pred Performance dictionary with the right column names to match what MeetOpt (MO) wants

In [ ]:

```
# Do this for Team_A and then make a new function after getting it to work
# Drop all the peformance columns for B, C, and D relays. They are all identical to the A values
TeamA_Perf_df_MO = TeamA_Perf_wM_df.loc[:,~TeamA_Perf_wM_df.columns.str.endswith(('B','C','D'))]

# List the columns of the predicted performance list
pred_perf_events = TeamA_Perf_df_MO.columns.tolist()
print(pred_perf_events)
```

```
['FLM50A', 'F2M50A', 'F3M50A', 'F4M50A', 'F11650Y', 'F1200Y', 'F2100Y', 'F3100Y', 'F4200Y', 'F150Y', 'F1100Y', 'F2200Y', 'F3200Y', 'F1500Y', 'F4100Y', 'F52
00Y', 'FLF50A', 'F1F50A']
```

In [ ]:

```
# Get list of swimmers from Team A
TeamA_swimmers = TeamA_Perf_df_MO.index.values.tolist()

print(TeamA_swimmers)
```

```
[167013, 214963, 221480, 228451, 233487, 233650, 235482, 255871, 256775, 260001, 265562, 270043, 329465, 330237, 330324, 342607, 342611, 344005, 347298, 35
6813, 382148, 395502, 402879, 403012, 409578, 586800]
```

In [ ]:

```
# Create the TeamA dictionary in the right structure
# Convert pandas to dict and use Swimmer as row index and Event as columns
TeamA_Perf_dict = TeamA_Perf_df_MO.to_dict(orient='index')
# Show the values
TeamA_Perf_dict[167013]['FLF50A']
```

```
Out[ ]: 105.96
```

```python
# Get the number of opponent lineups (scenarios) and their associated probabilities
# These will be generated from game theory later

# Need to use this structre for MeetOpt and to allow for more than one scenario later
# for 3 lineups
# opp_lineup_nums = [1,2,3]
# opp_lineup_num = (.1,.5,.4)
oppB_lineup_nums = [1]
oppB_lineup_select_prob = (1,)

# connect the lineup nums with their associate probs in a dictionary for MeetOpt
oppB_scenario_prob = dict(zip(oppB_lineup_nums,oppB_lineup_select_prob))

print(oppB_scenario_prob)
```

```
{1: 1}
```

```python
# Necessary lists and dicts for MeetOpt
individual_scored_events = ('F1200Y', 'F150Y', 'F1100Y', 'F4100Y','F2100Y', 'F2200Y', 'F1500Y', 'F5200Y', 'F3100Y','F4200Y','F3200Y','F11650Y')
relay_scored_events = ('M50','F50')
relay_noMR = ('F50',)
indiv_pastperf_events = individual_scored_events

relay_pastperf_events = ('FLM50A', 'F2M50A','F3M50A', 'F4M50A', 'FLF50A', 'F1F50A')
MR_legs = ('FLM50A', 'F2M50A','F3M50A', 'F4M50A')


# the events in opptime for ranking
total_scored_events = individual_scored_events + relay_scored_events

# the events in pred_perf for performance prediction
total_pastperf_events = indiv_pastperf_events + relay_pastperf_events

# Lineup_Events are the events for assignment from the x,y,z variables (1st, 2nd, 3rd) from within MeetOpt

print(total_scored_events)
print(total_pastperf_events)
print(Lineup_Events)
```

```
('F1200Y', 'F150Y', 'F1100Y', 'F4100Y', 'F2100Y', 'F2200Y', 'F1500Y', 'F5200Y', 'F3100Y', 'F4200Y', 'F3200Y', 'F11650Y', 'M50', 'F50')
('F1200Y', 'F150Y', 'F1100Y', 'F4100Y', 'F2100Y', 'F2200Y', 'F1500Y', 'F5200Y', 'F3100Y', 'F4200Y', 'F3200Y', 'F11650Y', 'FLM50A', 'F2M50A', 'F3M50A', 'F4M
50A', 'FLF50A', 'F1F50A')
('F1200Y', 'F150Y', 'F1100Y', 'F4100Y', 'F2100Y', 'F2200Y', 'F1500Y', 'F5200Y', 'F3100Y', 'F4200Y', 'F3200Y', 'F11650Y', 'FLM50A', 'F2M50A', 'F3M50A', 'F4M
50A', 'FLM50B', 'F2M50B', 'F3M50B', 'F4M50B', 'FLM50C', 'F2M50C', 'F3M50C', 'F4M50C', 'FLM50D', 'F2M50D', 'F3M50D', 'F4M50D', 'FLF50A', 'F1F50A', 'FLF50B',
'F1F50B', 'FLF50C', 'F1F50C', 'FLF50D', 'F1F50D')
```

Input the MeetOpt function to create an improved lineup vs. an opponent or distribution of opponents.

```python
#Import PuLP modeller functions
from math import *
```

```python
import pulp as pl
import time
import os

"""
Created on Sat Jan 12 09:14:40 2019

@author: mdb025
"""

def MeetOpt(athleteFull,scenario,scenprob,indiv_events,relay_scored_events,relaynoMR,stroke,relay_pastperf_events,lineup_events, playperf,opptime, Big_M):
    """
    :param athletFull: list of athlete IDs
    :param scenario: integer list of the opponent lineups, e.g. [1, 2]
    :param scenprob: dictionary of scenarios to probability (or weight) of selection. This will be the
    the likelihood that the lineup is chosen from a game theory distribution.
    :param indiv_scored_events: a list of the names of the events that are scored in a meet for the individuals
    :param relaynoMR: the list of names of scored freestyle relay events (no medleys)
    :param stroke: the list of names of the legs of the medley relay
    :param relay_scored_events: names of relay events scored and in opptime
    :param lineup_events: the events list that need to be returned for Team A includes relays A,B,C data from xvar, yvar, zvar.
    :param playperf: the dictionary of predicted performances for Team A athletes in each event. indexed by (indiv_scored_events and relay_past_perf_events
    :param opptime: the dictionary of opposing team ranked performances. Indexed by scenario (lineup), rank (1,2,3,4,5), events (indiv_scored_events and re
    :param Bib_M: dictionary of the BigM values for missing times for the scoring events and legs.

    #returns optimal response line up to the given opponent lineup(s) (called scenarios)

    """

    print("NOW WE'RE IN MEETOPT: \n")


    ## Begin INPUT SETTINGS
    # 1 if want to write output to file at the following path
    # WriteOutput = 0
    # path of the output file adjust for user
    # if WriteOutput == 1:
    #    path = "G:\My Drive\SwimMeetOpt" + "\SwimMeetOptTrialResults.csv"

    # Used for comparison
    tot_scored_events = indiv_events + relay_scored_events
    tot_pastperf_events = indiv_events + relay_pastperf_events
    tot_assgn_events = lineup_events
    relay = relay_scored_events

    #tuples for dictionaries
    event_noMR = indiv_events + relaynoMR
    print("event_noMR: ", event_noMR)
    print(scenprob)
    print("total SCORED events: ", tot_scored_events)
    print("total PERF events: ", tot_pastperf_events)
    print("total ASSIGNED events:", lineup_events)

    homerank = (1,2,3)
    place = (1,2,3,4,5,6)
    ind_points = (9, 4, 3, 2, 1, 0)
```

```python
relay_points = (11,4,2,0,0,0)
indivplcscore = dict(zip(place,ind_points))
relayplcscore = dict(zip(place,relay_points))

indiv = indiv_events

#Do these exist in college?
Maxevent = 4
Maxrelayevent = 1
Maxindevent = 3

TopopprankIndiv = 5
TopopprankRelay = 3


#Set solve time limit in seconds and optimality gap
MaxSolveTime = 10
SolverTimeLimit = MaxSolveTime*60
OptGap = 0.01
#Which Solver?
SolverUsed = "Gurobi"
#SolverUsed = "Gurobi"

if SolverUsed == "CBC":
    #Choose solver, and set it to problem, and build the model
    #Solve with CBC with logging and time limit. Parameter option: keepFiles=1 breaks it!
    #solver = pl.COIN_CMD(msg=1, keepFiles=1, presolve=0, threads=1, maxSeconds=SolverTimeLimit,fracGap = OptGap)
    #solver = pulp.COIN_CMD(msg=1, keepFiles=1, presolve=1, maxSeconds=SolverTimeLimit,fracGap=OptGap)
    pl.PULP_CBC_CMD()
else:
    #Solve with Gurobi
    #solver = pulp.GUROBI_CMD(keepFiles=1,options=[("MIPFocus",1),("TimeLimit",SolverTimeLimit)])
    #solver = pl.GUROBI_CMD(keepFiles=1,options=[("MIPFocus",1),("MIPGap",OptGap),("TimeLimit",SolverTimeLimit)])
    solver = pl.GUROBI()
    #Solve with Cplex. Throws error for write sol file
    #solver = pulp.CPLEX_scCMD(msg=1,options = ['set mip tolerances mipgap 0.2'])
    #solver = pulp.CPLEX_CMD(msg=1,timelimit=30)


#highest relative rank for home
Tophomerank = 3;
# small constant
EPS = 0.0001;
#number of people on a relay team
relaySize = 4;

#subset of the actual athletes with some
#ghosts because of hard relay requirements
#realathlete are only the actual athletes
# ActAthNum = len(athleteFull)
# athlete = athleteFull[:int(ActAthNum)+4]
# realathlete = athleteFull[:int(ActAthNum)]

athlete = athleteFull
# for i in realathlete:
#     print("current realathlete index ", realathlete[realathlete.index(i)])
```

```
#     print("previous athlete ", realathlete[realathlete.index(i)-1])


#OUTPUT Arrays and Variables

#Start the clock for first setup
setupStart = time.time()

print("Check Done")

#Instantiate our problem class
SwimMeetOpt = pl.LpProblem("MeetMax", pl.LpMaximize)

#Initialize the decision variables
#Scenario scores vs. opps
scenscorevars = {}
# if assigned athlete has 1st time in event
xvars = {}
# if assigned athlete has 2nd best time in event
yvars = {}
# if assigned athlete has 3rd best time in event
zvars = {}
# if assigned athlete has 1st time in start time in event 200MR
xvarleads = {}
# if assigned athlete has 2nd best time in start time in event 200MR
yvarleads = {}
# if assigned athlete has 3rd best time in start time in event 200MR
zvarleads = {}
# if assigned athlete has 1st time in medley
xMRvars = {}
# if assigned athlete has 2nd best time in medley
yMRvars = {}
# if assigned athlete has 3rd best time in medley
zMRvars = {}
# rank of our athletes assigned to events
rvars = {}
#indicator variables of for outcome of event j versus opp 1
wvars = {}
#assignments
asgnvars = {}

#OPTIMIZATION DECISION VARIABLES defined in the MeetOpt paper using PuLP:

#scenscorevar is a placeholder which will hold the expected score of our optimal
#lineup against the lineup given in scenario i
scenscorevar = pl.LpVariable.dicts('scenscorevar',(scenario),0,None,pl.LpContinuous)

#these are placement variables for our athletes to events
#xvar will hold the best assigned athlete from our team in an event
#yvar will hold the second best assigned athlete from our team in an event
#zvar will hold the third best assigned athlete from our team in an event
#We assume that exactly three athletes are assigned to each event
#the optimization creates the assignment and the ordering
xvar = pl.LpVariable.dicts('xvar',(athlete,indiv),0,1,pl.LpBinary)
yvar = pl.LpVariable.dicts('yvar',(athlete,indiv),0,1,pl.LpBinary)
zvar = pl.LpVariable.dicts('zvar',(athlete,indiv),0,1,pl.LpBinary)
```

```python
#Same as above, but the starting leg for the "non-Medley freestyle Relay" relays
xFRvarlead = pl.LpVariable.dicts('xFRvarlead',(athlete,relaynoMR),0,1,pl.LpBinary)
yFRvarlead = pl.LpVariable.dicts('yFRvarlead',(athlete,relaynoMR),0,1,pl.LpBinary)
zFRvarlead = pl.LpVariable.dicts('zFRvarlead',(athlete,relaynoMR),0,1,pl.LpBinary)

#Same ordering as above, but for the athletes assigned to the
#best, second best, and third best LEGS of Freestyle relay
xFRvar = pl.LpVariable.dicts('xFRvar',(athlete, relaynoMR),0,1,pl.LpBinary)
yFRvar = pl.LpVariable.dicts('yFRvar',(athlete, relaynoMR),0,1,pl.LpBinary)
zFRvar = pl.LpVariable.dicts('zFRvar',(athlete, relaynoMR),0,1,pl.LpBinary)

#Same ordering as above, but for the athletes assigned to the
#best, second best, and third best medley relay
xMRvar = pl.LpVariable.dicts('xMRvar',(athlete, stroke),0,1,pl.LpBinary)
yMRvar = pl.LpVariable.dicts('yMRvar',(athlete, stroke),0,1,pl.LpBinary)
zMRvar = pl.LpVariable.dicts('zMRvar',(athlete, stroke),0,1,pl.LpBinary)

#rvar will hold the TIME of our first, second, and third fastest entrants in each event
rvar = pl.LpVariable.dicts('rvar',(homerank,tot_scored_events),None,None,pl.LpContinuous)
#wvar will be 1 if our athlete with homerank h, in event j, finishes in overall place k, against
#opponent scenario l
#with this we can answer in which place our assigned athletes actually finish and score the meet!
wvar = pl.LpVariable.dicts('wvar',(tot_scored_events,homerank, place, scenario),0,1,pl.LpBinary)
#asgnvar is a generic variable which will be 1 if athlete i is assigned to event j (ignoring rank, etc.)
#just answers the question "Is this athlete doing in this event?"
#asgnvar = pl.LpVariable.dicts('asgnvar',(athlete,tot_assgn_events),0,1,pl.LpBinary)


#Objective Function - Maximize the weighted scenario (or expected) score against
#over eact scenario (or against each team)
SwimMeetOpt += pl.lpSum(scenprob[s]*scenscorevar[s] for s in scenario), "Total Expected Score"
print("obj done")

# Multiple relay teams and they cannot sweep so only the top two relay teams are included in the home team score
# defines the variable scenscorevar (scenario score variable) for each scenario
for s in scenario:
    SwimMeetOpt += scenscorevar[s] == pl.lpSum(indivplcscore[p]*wvar[j][k][p][s] for j in indiv for k in homerank for p in place if k<=p) + \
        pl.lpSum(relayplcscore[p]*wvar[j][k][p][s] for j in relay_scored_events for k in homerank for p in place if k<=p) + \
        pl.lpSum(2*wvar[j][1][4][s] - 2*wvar[j][3][3][s] for j in relay_scored_events), "Scenario %s Score"%s


#CREATING THE CONSTRAINTS FOR THE OPTIMIZATION PROBLEM:

# Exactly one 1st, 2nd, 3rd best time athlete in each indiv event

# WARNING 5/27/21 Make this strict, but assumes you have enough athletes to field 3 in every indiv event, and 12 in each relay under the max event rule
for j in indiv:
    SwimMeetOpt += pl.lpSum(xvar[i][j] for i in athlete)  == 1, "Exactly one 1st for indiv event %s"%j
    SwimMeetOpt += pl.lpSum(yvar[i][j] for i in athlete)  == 1, "Exactly one 2nd for indiv event %s"%j
    SwimMeetOpt += pl.lpSum(zvar[i][j] for i in athlete)  == 1, "Exactly one 3rd for indiv event %s"%j

# Exactly 4 athletes in a relay for our first, second, and third relays
# accounting for the opening leg not being a flying start in the non-MR relays
for j in relaynoMR:
```

```
    SwimMeetOpt += pl.lpSum(xFRvar[i][j] for i in athlete) == relaySize-1, "Exactly 3 legs in 1st relay %s"%j
    SwimMeetOpt += pl.lpSum(yFRvar[i][j] for i in athlete) == relaySize-1, "Exactly 3 legs in 2nd relay %s"%j
    SwimMeetOpt += pl.lpSum(zFRvar[i][j] for i in athlete) == relaySize-1, "Exactly 3 legs in 3rd relay %s"%j
    SwimMeetOpt += pl.lpSum(xFRvarlead[i][j] for i in athlete) == 1, "Exactly 1 to start 1st relay %s"%j
    SwimMeetOpt += pl.lpSum(yFRvarlead[i][j] for i in athlete) == 1, "Exactly 1 to start 2nd relay %s"%j
    SwimMeetOpt += pl.lpSum(zFRvarlead[i][j] for i in athlete) == 1, "Exactly 1 to start 3rd relay %s"%j

# Exactly 4 athletes in the first, second, and third best medley relay
SwimMeetOpt += pl.lpSum(xMRvar[i][j] for i in athlete for j in stroke) == relaySize, "Exactly 4 in 1st MR"
SwimMeetOpt += pl.lpSum(yMRvar[i][j] for i in athlete for j in stroke) == relaySize, "Exactly 4 in 2nd MR"
SwimMeetOpt += pl.lpSum(zMRvar[i][j] for i in athlete for j in stroke) == relaySize, "Exactly 4 in 3rd MR"

# Athletes in at most Maxevent
for i in athlete:
    SwimMeetOpt += pl.lpSum(xvar[i][j] + yvar[i][j] + zvar[i][j] for j in indiv)  + pl.lpSum(xFRvar[i][j] + yFRvar[i][j] + zFRvar[i][j] + xFRvarlead[i]

# Athletes in at most Maxrelayevent
for i in athlete:
    SwimMeetOpt += pl.lpSum(xFRvar[i][j] + yFRvar[i][j] + zFRvar[i][j] + xFRvarlead[i][j] + yFRvarlead[i][j] + zFRvarlead[i][j] for j in relaynoMR)+ pl
    # Athletes in at most Maxindivevent
    SwimMeetOpt += pl.lpSum(xvar[i][j] + yvar[i][j] + zvar[i][j] for j in indiv) <= Maxindevent,"Max Indiv events for athlete %s"%i

    # Back to back event constraints
    #HARD CODED WITH EVENT NAMES AND NEEDS TO BE CHECKED
    '''
    SwimMeetOpt += xvar[i]["100F"] + yvar[i]["100F"] + zvar[i]["100F"] + xvar[i]["500F"] + yvar[i]["500F"] + zvar[i]["500F"]<= 1,"No back to back 100F/
    SwimMeetOpt += xvar[i]["200F"] + yvar[i]["200F"] + zvar[i]["200F"] + xvar[i]["200IM"] + yvar[i]["200IM"] + zvar[i]["200IM"]<= 1,"No back to back 20
    SwimMeetOpt += xvar[i]["100BS"] + yvar[i]["100BS"] + zvar[i]["100BS"] + xvar[i]["100BR"] + yvar[i]["100BR"] + zvar[i]["100BR"]<= 1,"No back to back
    '''

    # Athletes can only be one of the 1st, 2nd, or 3rd ranked atheletes assigned to an event j
    for j in indiv:
        SwimMeetOpt += xvar[i][j] + yvar[i][j] + zvar[i][j] <= 1,"athlete %s can only be one of the 1st, 2nd, or 3rd ranked athletes assigned to an eve

#Athletes can only be 1st, 2nd, or 3rd ranked relay team for each relay j
for i in athlete:
    for j in relaynoMR:
        SwimMeetOpt += xFRvar[i][j] + yFRvar[i][j] + zFRvar[i][j] + xFRvarlead[i][j] + yFRvarlead[i][j] + zFRvarlead[i][j] <= 1,"athlete %s can only be

    # Each athlete can only perform one stroke in medley relay
    SwimMeetOpt += pl.lpSum(xMRvar[i][j]+yMRvar[i][j]+zMRvar[i][j] for j in stroke) <= 1, "Athlete %s can only perform one stroke in medley relay"%i


#Each stroke on each relay team can only have one athlete assigned
for j in stroke:
    SwimMeetOpt += pl.lpSum(xMRvar[i][j]for i in athlete) <= 1, "Stroke %s on 1st MR can only have one athlete"%j
    SwimMeetOpt += pl.lpSum(yMRvar[i][j]for i in athlete) <= 1, "Stroke %s on 2nd MR can only have one athlete"%j
    SwimMeetOpt += pl.lpSum(zMRvar[i][j]for i in athlete) <= 1, "Stroke %s on 3rd MR can only have one athlete"%j

#realized rank of athletes from assignments
#IF NO RUNNER NEED TO ASSIGN A time larger than the third runner, smaller than the BigM for rank
for j in indiv:
    SwimMeetOpt += rvar[1][j] == pl.lpSum(playperf[i][j]*xvar[i][j] for i in athlete) + 0.5*Big_M[j] + 1.0 - pl.lpSum(xvar[i][j]*(0.5*Big_M[j] + 1) for
    SwimMeetOpt += rvar[2][j] == pl.lpSum(playperf[i][j]*yvar[i][j] for i in athlete) + 0.5*Big_M[j] + 2.0 - pl.lpSum(yvar[i][j]*(0.5*Big_M[j] + 2) for
    SwimMeetOpt += rvar[3][j] == pl.lpSum(playperf[i][j]*zvar[i][j] for i in athlete) + 0.5*Big_M[j] + 3.0 - pl.lpSum(zvar[i][j]*(0.5*Big_M[j] + 3) for
```

```
 # The problem data is written to an .lp file
#SwimMeetOpt.writeLP("SwimMeetOpt.lp")

#WARNING: Sloppy hard code fix for legacy data structure
playperfLeg = dict()
playperfLead = dict()
for i in athlete:
    # declare dicts
    playperfLeg[i] = dict()
    playperfLead[i] = dict()
    for j in relaynoMR:
        playperfLeg[i][j] = playperf[i]['F1F50A']
        playperfLead[i][j] = playperf[i]['FLF50A']

for j in relaynoMR:
    SwimMeetOpt += rvar[1][j] == pl.lpSum(playperfLeg[i][j]*xFRvar[i][j] + playperfLead[i][j]*xFRvarlead[i][j] for i in athlete) + relaySize*0.5*Big_M[
    SwimMeetOpt += rvar[2][j] == pl.lpSum(playperfLeg[i][j]*yFRvar[i][j] + playperfLead[i][j]*yFRvarlead[i][j] for i in athlete) + relaySize*0.5*Big_M[
    SwimMeetOpt += rvar[3][j] == pl.lpSum(playperfLeg[i][j]*zFRvar[i][j] + playperfLead[i][j]*zFRvarlead[i][j] for i in athlete) + relaySize*0.5*Big_M[

SwimMeetOpt += rvar[1]["M50"] == pl.lpSum(playperf[i][j]*xMRvar[i][j] for i in athlete for j in stroke) + relaySize*0.5*Big_M["M50"] + relaySize*1.0 -
SwimMeetOpt += rvar[2]["M50"] == pl.lpSum(playperf[i][j]*yMRvar[i][j] for i in athlete for j in stroke) + relaySize*0.5*Big_M["M50"] + relaySize*2.0 -
SwimMeetOpt += rvar[3]["M50"] == pl.lpSum(playperf[i][j]*zMRvar[i][j] for i in athlete for j in stroke) + relaySize*0.5*Big_M["M50"] + relaySize*3.0 -

#force consistency in rank order
for k in homerank:
    for j in tot_scored_events:
        if k < Tophomerank:
            SwimMeetOpt += rvar[k][j] <= rvar[k+1][j]

#runner/team of rank k can be place in at most one place (1st, 2nd, or 3rd) vs opp 1
for j in indiv:
    for k in homerank:
        for s in scenario:
            SwimMeetOpt += pl.lpSum(wvar[j][k][l][s] for l in place if l >= k) <= 1
for j in relay:
    for k in homerank:
        for s in scenario:
            SwimMeetOpt += pl.lpSum(wvar[j][k][l][s] for l in place if l >= k) <= 1

#Did your first runner 1st runner 1st, 2nd in 2nd or 3rd in third vs opp
for j in indiv:
    for k in homerank:
        for l in place:
            for s in scenario:
                if k==l:
                    #print("ath: ",j,"homerank: ",k,"place: ",l, "scen: ",s)
                    SwimMeetOpt += rvar[k][j] <= opptime[s][1][j]*wvar[j][k][l][s] + Big_M[j] - Big_M[j]*wvar[j][k][l][s]
                if l>k and l<(TopopprankIndiv + k):
                    #print("ath: ",j,"homerank: ",k,"place: ",l, "scen: ",s, "l-k+1: ", l-k+1)
                    SwimMeetOpt += rvar[k][j] <= opptime[s][l-k+1][j]*wvar[j][k][l][s] + Big_M[j] - Big_M[j]*wvar[j][k][l][s]
                if l>k  and l<=(TopopprankIndiv + k):
                    #print("ath: ",j,"homerank: ",k,"place: ",l, "scen: ",s, "l-k: ", l-k)
                    SwimMeetOpt += rvar[k][j] >= opptime[s][l-k][j]*wvar[j][k][l][s]

#Did your first relay 1st runner 1st, 2nd in 2nd or 3rd in third vs opp
for j in relay:
```

```
    for k in homerank:
        for l in place:
            for s in scenario:
                if k==l:
                    SwimMeetOpt += rvar[k][j] <= opptime[s][1][j]*wvar[j][k][l][s] + 5*Big_M[j]- 5*Big_M[j]*wvar[j][k][l][s]
                if l>k and l< (TopopprankRelay + k):
                    SwimMeetOpt += rvar[k][j] <= opptime[s][l-k+1][j]*wvar[j][k][l][s] + 5*Big_M[j]- 5*Big_M[j]*wvar[j][k][l][s]
                if l>k  and l<=(TopopprankRelay + k):
                    SwimMeetOpt += rvar[k][j] >= opptime[s][l-k][j]*wvar[j][k][l][s]


#Report the total setup time
setupStop = time.time()
print("Total Setup Time = ", int(setupStop - setupStart), " secs")

# The problem data is written to an .lp file
SwimMeetOpt.writeLP("SwimMeetOpt.lp")

SwimMeetOpt.setSolver(solver)

#Solve the WHOLE problem with selected Solver
print("Solve the baseline problem:")
solveStart = time.time()
SwimMeetOpt.solve()
solveStop = time.time()
print(" Total Solve Time = ", int((solveStop - solveStart)/60.0), " mins")

#The status of the solution is printed to the screen
print(" Status:", pl.LpStatus[SwimMeetOpt.status])
print(" Objective:", pl.value(SwimMeetOpt.objective), " points")

#Return the objective function value for the best feasible soln found
BestObjective = pl.lpSum(scenprob[s]*scenscorevar[s].varValue for s in scenario)
print(" Best Found Solution Objective= ", BestObjective)

OptObj = pl.value(SwimMeetOpt.objective)
scenscore = dict()
for s in scenario:
    scenscore[s] = scenscorevar[s].varValue
    print(" Score under Scenario ",s, "is ", int(scenscorevar[s].varValue))


# Each of the variables is printed with it's resolved optimum value

optLineup = {}
for i in athlete:
    optLineup[i] = {}
    for j in indiv:
        optLineup[i][j] = xvar[i][j].varValue + yvar[i][j].varValue + zvar[i][j].varValue
    # TO DO!! Add code for other relays
    optLineup[i]['FLF50A'] = xFRvarlead[i]['F50'].varValue
    optLineup[i]['F1F50A'] = xFRvar[i]['F50'].varValue
    optLineup[i]['FLF50B'] = yFRvarlead[i]['F50'].varValue
    optLineup[i]['F1F50B'] = yFRvar[i]['F50'].varValue
    optLineup[i]['FLF50C'] = zFRvarlead[i]['F50'].varValue
    optLineup[i]['F1F50C'] = zFRvar[i]['F50'].varValue
```

```python
        # No need for D teams
        optLineup[i]['FLF50D'] = 0
        optLineup[i]['F1F50D'] = 0

        for j in stroke:
            leg = j[:-1]
            optLineup[i][leg+'A'] = xMRvar[i][j].varValue
            optLineup[i][leg+'B'] = yMRvar[i][j].varValue
            optLineup[i][leg+'C'] = zMRvar[i][j].varValue

            # No need for D teams
            optLineup[i][leg+'D'] = 0

    HomeAthPredTime = {}
    HomeAthFinPlace = {}
    for j in tot_scored_events:
        HomeAthPredTime[j] = {}
        HomeAthFinPlace[j] = {}
        for k in homerank:
            # mins = int(rvar[k][j].varValue/60)
            # secs = rvar[k][j].varValue - mins*60
            # HomeAthPredTime[j][k] = str(mins)+":"+str(secs)
            HomeAthPredTime[j][k] = rvar[k][j].varValue
            for p in place:
                if wvar[j][k][p][1].varValue == 1:
                    HomeAthFinPlace[j][k] = p

    # END: Save the finish place and time
    ##########################

    #Return the lineup found in form of a 2-D dictionary of assignment for each athlete
    #NEED this to match the events and A/B/C team of relays.
    optlineup_df = pd.DataFrame.from_dict(optLineup)
    optLUtime_df = pd.DataFrame.from_dict(HomeAthPredTime)
    optLUplace_df = pd.DataFrame.from_dict(HomeAthFinPlace)

    # Return the transpose to get swimmers as index
    return optlineup_df.T, optLUtime_df, optLUplace_df
```

In [ ]:

```python
#pl.pulpTestAll()
```

In [ ]:

```python
pl.listSolvers(onlyAvailable=True)
```

```
No parameters matching '_test' found
['GLPK_CMD', 'GUROBI', 'GUROBI_CMD']
```

Out[ ]:

Create the new lineup for Team A in response to Team B's lineup

In [ ]:

```python
# def MeetOpt(athleteFull,scenario,scenprob,indiv_events,relay_scored_events,relaynoMR,stroke,relay_pastperf_events,lineup_events, playperf,opptime):

# Test MeetOpt inputs and outputs
```

```python
TeamA_Lineup_df[1],_,_ = MeetOpt(TeamA_swimmers, oppB_lineup_nums, oppB_scenario_prob, individual_scored_events, \
    relay_scored_events, relay_noMR, MR_legs,relay_pastperf_events,Lineup_Events,TeamA_Perf_dict,opptime_TeamB_dict,BigM)

# Reorder the columns to the meet event order
TeamA_Lineup_df[1] = TeamA_Lineup_df[1][EventOrder]
```

```
NOW WE'RE IN MEETOPT:

event_noMR:  ('F1200Y', 'F150Y', 'F1100Y', 'F4100Y', 'F2100Y', 'F2200Y', 'F1500Y', 'F5200Y', 'F3100Y', 'F4200Y', 'F3200Y', 'F11650Y', 'F50')
{1: 1}
total SCORED events:  ('F1200Y', 'F150Y', 'F1100Y', 'F4100Y', 'F2100Y', 'F2200Y', 'F1500Y', 'F5200Y', 'F3100Y', 'F4200Y', 'F3200Y', 'F11650Y', 'M50', 'F5
0')
total PERF events:  ('F1200Y', 'F150Y', 'F1100Y', 'F4100Y', 'F2100Y', 'F2200Y', 'F1500Y', 'F5200Y', 'F3100Y', 'F4200Y', 'F3200Y', 'F11650Y', 'FLM50A', 'F2M
50A', 'F3M50A', 'F4M50A', 'FLF50A', 'F1F50A')
total ASSIGNED events: ('F1200Y', 'F150Y', 'F1100Y', 'F4100Y', 'F2100Y', 'F2200Y', 'F1500Y', 'F5200Y', 'F3100Y', 'F4200Y', 'F3200Y', 'F11650Y', 'FLM50A',
'F2M50A', 'F3M50A', 'F4M50A', 'FLM50B', 'F2M50B', 'F3M50B', 'F4M50B', 'FLM50C', 'F2M50C', 'F3M50C', 'F4M50C', 'FLM50D', 'F2M50D', 'F3M50D', 'F4M50D', 'FLF5
0A', 'F1F50A', 'FLF50B', 'F1F50B', 'FLF50C', 'F1F50C', 'FLF50D', 'F1F50D')
Check Done
obj done
Total Setup Time =  0  secs
Solve the baseline problem:
Gurobi Optimizer version 9.5.1 build v9.5.1rc2 (win64)
Thread count: 4 physical cores, 8 logical processors, using up to 8 threads
Optimize a model with 960 rows, 1657 columns and 8493 nonzeros
Model fingerprint: 0x64a65c1a
Variable types: 43 continuous, 1614 integer (0 binary)
Coefficient statistics:
  Matrix range     [1e-03, 4e+03]
  Objective range  [1e+00, 1e+00]
  Bounds range     [1e+00, 1e+00]
  RHS range        [1e+00, 4e+03]
Presolve removed 327 rows and 85 columns
Presolve time: 0.03s
Presolved: 633 rows, 1572 columns, 7224 nonzeros
Variable types: 0 continuous, 1572 integer (1530 binary)

Root relaxation: objective 1.778217e+02, 376 iterations, 0.01 seconds (0.00 work units)

    Nodes    |    Current Node    |     Objective Bounds      |     Work
 Expl Unexpl |  Obj  Depth IntInf | Incumbent    BestBd   Gap | It/Node Time

     0     0 176.80006    0   79          - 176.80006      -     -    0s
     0     0 151.83841    0   92          - 151.83841      -     -    0s
     0     0 151.83821    0   89          - 151.83821      -     -    0s
     0     0 149.39261    0   70          - 149.39261      -     -    0s
     0     0 149.38223    0   84          - 149.38223      -     -    0s
     0     0 149.38115    0   84          - 149.38115      -     -    0s
     0     0 147.20116    0   61          - 147.20116      -     -    0s
     0     0 146.92716    0   48          - 146.92716      -     -    0s
H    0     0                     141.0000000 146.91784  4.20%     -    0s
     0     0 146.91784    0   41  141.00000 146.91784  4.20%     -    0s
H    0     0                     143.0000000 146.91784  2.74%     -    0s
     0     0 146.00000    0   10  143.00000 146.00000  2.10%     -    0s
H    0     0                     146.0000000 146.00000  0.00%     -    0s
     0     0 146.00000    0   10  146.00000 146.00000  0.00%     -    0s
```

```
Cutting planes:
  Gomory: 3
  Cover: 30
  Clique: 24
  MIR: 26
  StrongCG: 5
  GUB cover: 41
  RLT: 5
  Relax-and-lift: 15

Explored 1 nodes (1275 simplex iterations) in 0.35 seconds (0.09 work units)
Thread count was 8 (of 8 available processors)

Solution count 3: 146 143 141

Optimal solution found (tolerance 1.00e-04)
Best objective 1.460000000000e+02, best bound 1.460000000000e+02, gap 0.0000%
Gurobi status= 2
 Total Solve Time =  0  mins
 Status: Optimal
 Objective: 146.0  points
 Best Found Solution Objective=  146.0
 Score under Scenario  1 is  146
```

In [ ]:

```
# Clean up the output (-0.0) by making all integers
TeamA_Lineup_df[1] = TeamA_Lineup_df[1][TeamA_Lineup_df[1].columns].astype('int8')
```

EDA on the new Lineup compared to the old

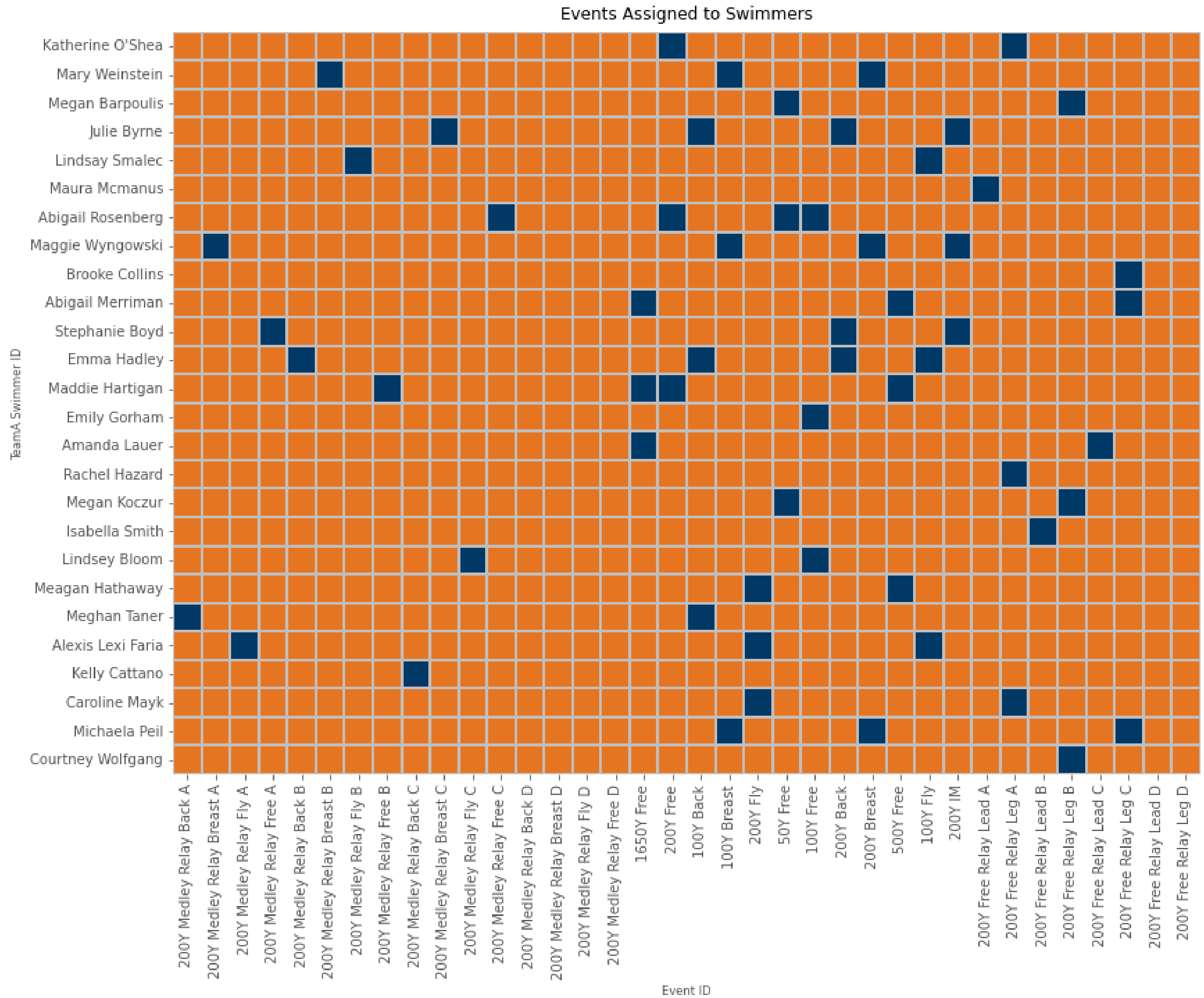
In [ ]:

```
def ChartLineup(TeamName, TeamColors, TeamLineup, FigSize_h, FigSize_l):
    """
    :param TeamName: String name of the Team for the lineup, e.g. 'Team A'
    :param TeamLineup: Dataframe of team lineup. Index is swimmer_id and columns are events
    :param TeamColors: list of matplotlib colors (2), e.g. [(0,.22,.4), (0.9,0.46,0.13)]
    :param FigSize_h, FigSize_l: figur height and width in inches.

    #returns plot of given lineup

    """
    # Check out the "new" lineup
    # Displaying dataframe as an heatmap with two categories
    fig, axs = plt.subplots(1, 1, figsize=(FigSize_h, FigSize_l), constrained_layout=True)

    # Make swimmer names the index
    Team_Lineup_Clean_df = pd.merge(left= TeamLineup, right= Swimmer_Names_df[['name']], how= 'left', left_index= True,right_index=True).set_index('name')

    Team_Lineup_Clean_df = Team_Lineup_Clean_df.rename(columns=EventLabelConvertDict)

    sns.heatmap(Team_Lineup_Clean_df, linewidth= 0.1, annot= False, cbar= False, square= True, ax= axs, cmap= TeamColors, linecolor= '.75')

    #clean up the charts
    fig.suptitle('Events Assigned to Swimmers')
    axs.set_ylabel('{} Swimmer ID'.format(TeamName),fontsize='small')
```

```python
    axs.set_xlabel('Event ID', fontsize='small')

    # colorbar = axs.collections[0].colorbar
    # colorbar.set_ticks([.25,.75])
    # colorbar.set_ticklabels(['Not Assigned','Assigned'])
    # #colorbar.ax.invert_yaxis()

    plt.show()

    return
```

In [ ]:

```python
# Check out the "new" lineup
ChartLineup('TeamA', TeamA_colors, TeamA_Lineup_df[1], 18, 10)
```

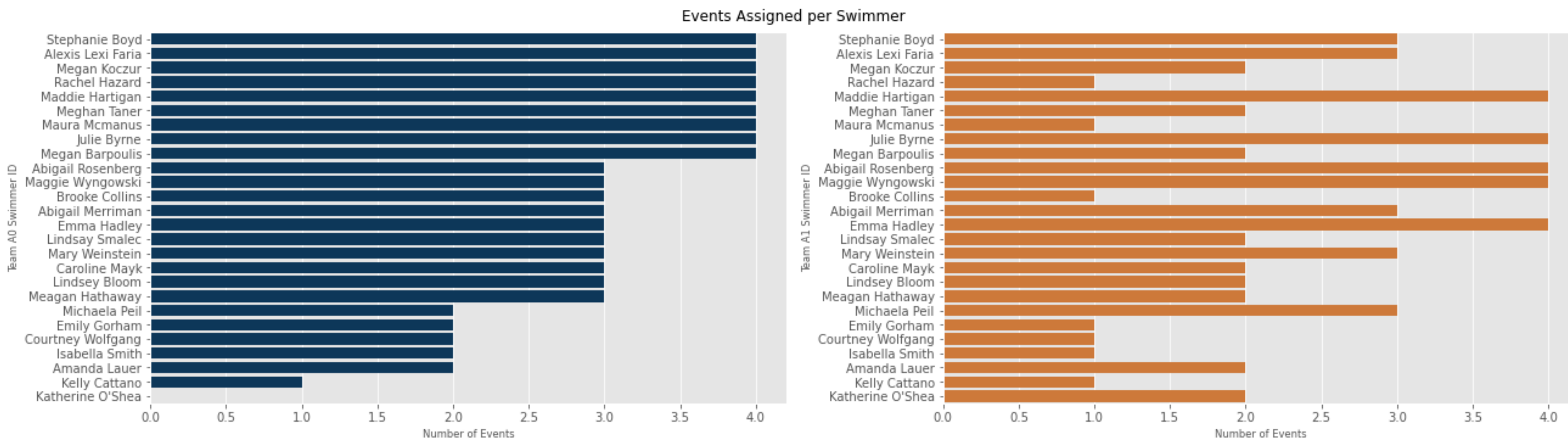


How have the total events per athlete changed?

In [ ]:

```
# How many Events for each swimmer?

fig, axs = plt.subplots(1, 2, figsize=(18, 5), constrained_layout=True)

# Team A Lineup 0
TeamA0_TotEventsPerAth = TeamA_Lineup_df[0].sum(axis=1).sort_values(ascending=False).to_frame().rename(columns={0: "tot_events"})
TeamA0_TotEventsPerAth = pd.merge(left= TeamA0_TotEventsPerAth, right= Swimmer_Names_df[['name']], how= 'left', left_index= True,right_index=True)
```

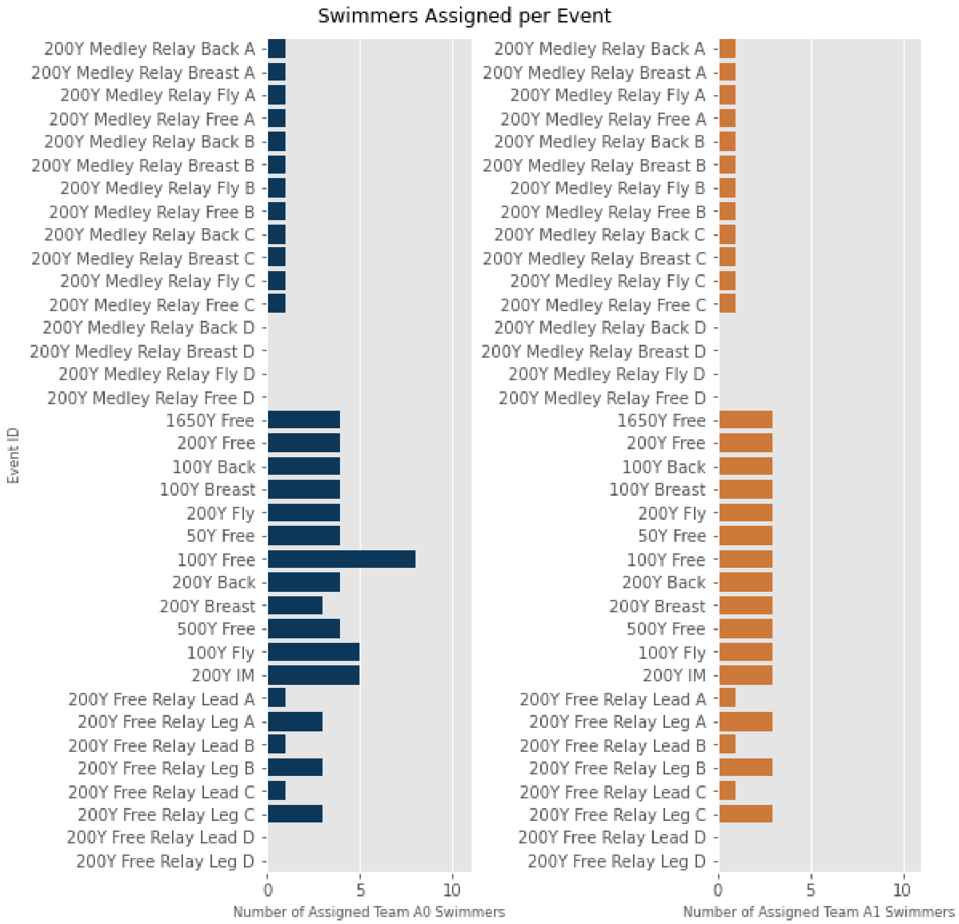
```python
sns.barplot(y=TeamA0_TotEventsPerAth.name, x=TeamA0_TotEventsPerAth.tot_events, order=TeamA0_TotEventsPerAth.name,color= TeamA_blue,ax=axs[0])

# Team A Lineup 1
TeamA1_TotEventsPerAth = TeamA_Lineup_df[1].sum(axis=1).to_frame().rename(columns={0: "tot_events"})
TeamA1_TotEventsPerAth = pd.merge(left= TeamA1_TotEventsPerAth, right= Swimmer_Names_df[['name']], how= 'left', left_index= True,right_index=True)
sns.barplot(y=TeamA1_TotEventsPerAth.name, x=TeamA1_TotEventsPerAth.tot_events, order=TeamA0_TotEventsPerAth.name, color = TeamA_orange,ax=axs[1])

#clean up the charts
fig.suptitle('Events Assigned per Swimmer')
axs[0].set_ylabel('Team A0 Swimmer ID',fontsize='small')
axs[1].set_ylabel('Team A1 Swimmer ID',fontsize='small')

#for ax in axs:
#    ax.set_ylim([0, 4.2])
axs[0].set_xlabel('Number of Events', fontsize='small')
axs[1].set_xlabel('Number of Events', fontsize='small')
plt.show()
```



In [ ]:

```python
# How many athletes for each event?

fig, axs = plt.subplots(1, 2, figsize=(8, 8), sharey=False, constrained_layout=True)

# Team A old
TeamA = TeamA_Lineup_df[0].rename(columns=EventLabelConvertDict).sum(axis=0)
sns.barplot(y=TeamA.index, x=TeamA.values, color= TeamA_blue,ax=axs[0], ci=None)

#Team A new
TeamA1 = TeamA_Lineup_df[1].rename(columns=EventLabelConvertDict).sum(axis=0)
sns.barplot(y=TeamA1.index, x=TeamA1.values, color= TeamA_orange, ax=axs[1], ci=None)

#clean up the charts
fig.suptitle('Swimmers Assigned per Event')
axs[0].set_ylabel('Event ID',fontsize='small')

for ax in axs:
```

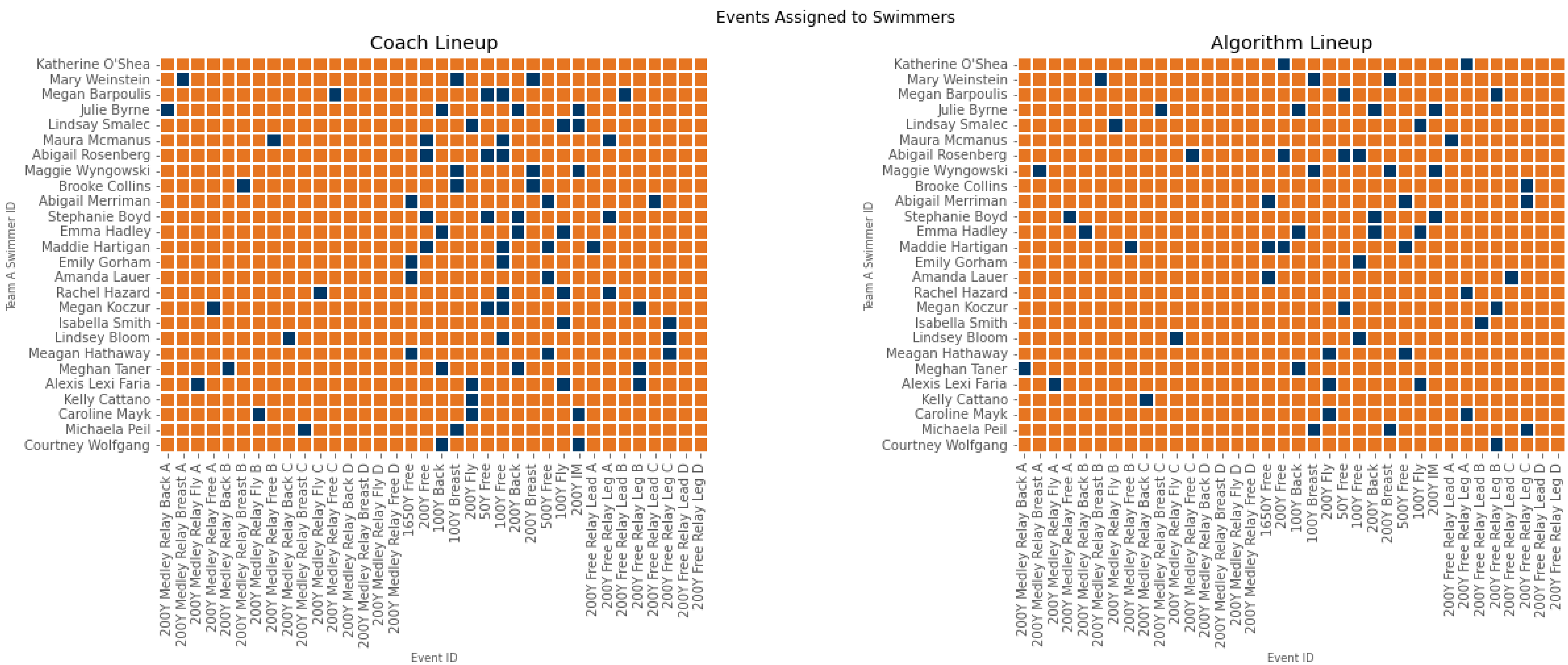
```
    ax.set_xlim([0, 11])
axs[0].set_xlabel('Number of Assigned Team A0 Swimmers', fontsize='small')
axs[1].set_xlabel('Number of Assigned Team A1 Swimmers', fontsize='small')
plt.show()
```



In [ ]:

```
# Displaying dataframe as a heatmap
fig, axs = plt.subplots(1, 2, figsize=(18, 7), constrained_layout=True)

# Make swimmer names the index
TeamA0_Lineup_Clean_df = pd.merge(left= TeamA_Lineup_df[0], right= Swimmer_Names_df[['name']], how= 'left', left_index= True,right_index=True).set_index('n
TeamA1_Lineup_Clean_df = pd.merge(left= TeamA_Lineup_df[1], right= Swimmer_Names_df[['name']], how= 'left', left_index= True,right_index=True).set_index('n

TeamA0_Lineup_Clean_df = TeamA0_Lineup_Clean_df.rename(columns=EventLabelConvertDict)
TeamA1_Lineup_Clean_df = TeamA1_Lineup_Clean_df.rename(columns=EventLabelConvertDict)

sns.heatmap(TeamA0_Lineup_Clean_df, linewidths = 0.30, annot = False, cbar= False, square= True, ax= axs[0], cmap= TeamA_colors )
sns.heatmap(TeamA1_Lineup_Clean_df, linewidths = 0.30, annot = False, cbar= False, square= True, ax= axs[1], cmap= TeamA_colors )

#clean up the charts
```

```
fig.suptitle('Events Assigned to Swimmers')
axs[0].set_ylabel('Team A Swimmer ID',fontsize='small')
axs[1].set_ylabel('Team A Swimmer ID',fontsize='small')

axs[0].set_xlabel('Event ID', fontsize='small')
axs[1].set_xlabel('Event ID', fontsize='small')

axs[0].set_title("Coach Lineup")
axs[1].set_title("Algorithm Lineup")

plt.show()
```



Highlight the differences between the two lineups

MAKE THIS A FUNCTION TO ACCEPT TWO LINEUPS AND RETURN THE DIFF LU_old and LU_new

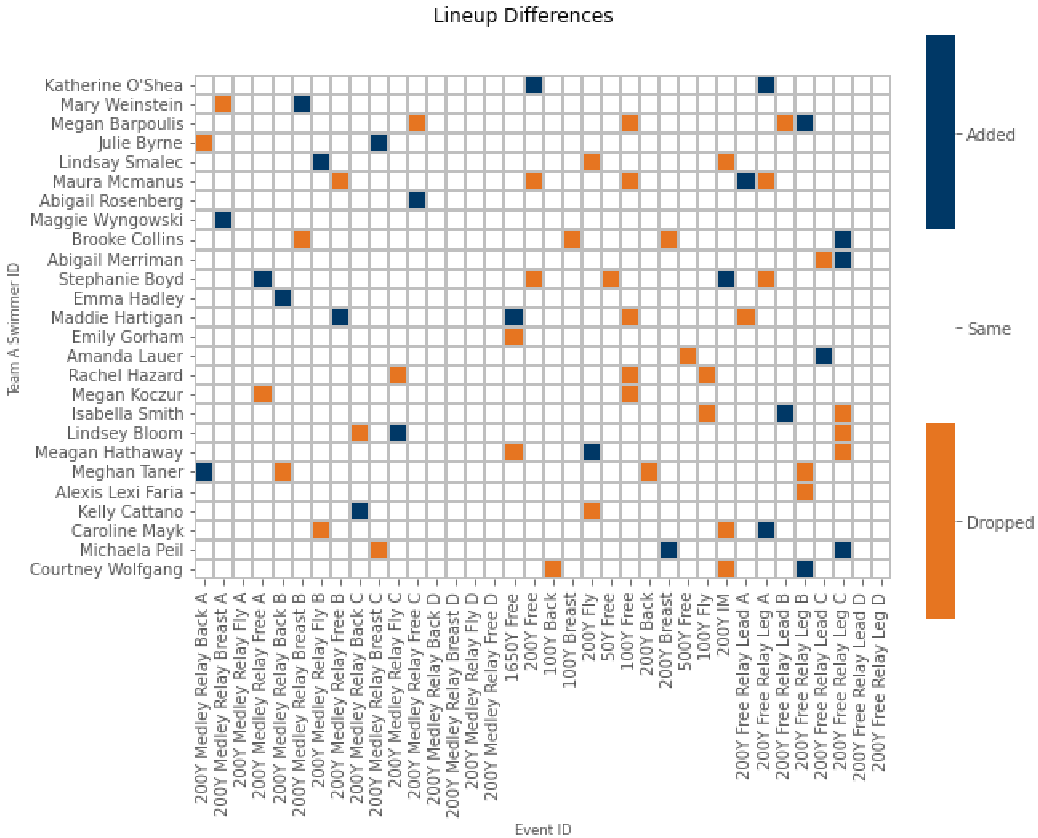
In [ ]:

```
def ChartLUdiff(TeamName,Team3color, LU_old, LU_new, FigSize_h, FigSize_l):
    """
    :param TeamName: String of Team name, e.g. 'Bucknell'
    :param LU_old: Dataframe of team lineup #1. Index is swimmer_id and columns are events
    :param LU_new: Dataframe of team lineup #2. Index is swimmer_id and columns are events
    :param Team3Color: Matplotlib color for Team B columns, e.g. [(0,.22,.4), (1,1,1), (0.9,0.46,0.13)]
    :param FigSize_h, FigSize_l: figur height and width in inches.
```

```
    #returns plot of given lineup

    """

    # Displaying dataframe of differences as a heatmap
    fig, ax = plt.subplots(1, 1, figsize=(FigSize_h, FigSize_l), constrained_layout=True)

    # values are 1/0, so + diff is an add in the new LU, 0 is no change, and -1 is dropped.
    sns.heatmap((LU_new - LU_old), linewidths = 0.10, annot = False, ax=ax, cbar= True, square= True, cmap= Team3color, linecolor='.75' )

    #clean up the charts
    fig.suptitle('Lineup Differences')
    ax.set_ylabel('{} Swimmer ID'.format(TeamName),fontsize='small')
    ax.set_xlabel('Event ID', fontsize='small')

    colorbar = ax.collections[0].colorbar
    colorbar.set_ticks([-2/3,0, 2/3])
    colorbar.set_ticklabels(['Dropped', 'Same', 'Added'])
    # #colorbar.ax.invert_yaxis()

    return
```

In [ ]:

```
TeamA_3colors = [TeamA_orange, (1,1,1), TeamA_blue ]
ChartLUdiff('Team A',TeamA_3colors, TeamA0_Lineup_Clean_df, TeamA1_Lineup_Clean_df, 9, 7)
```



Score the meet with the new lineup (137 vs 125 predicted for Team A under old lineup).

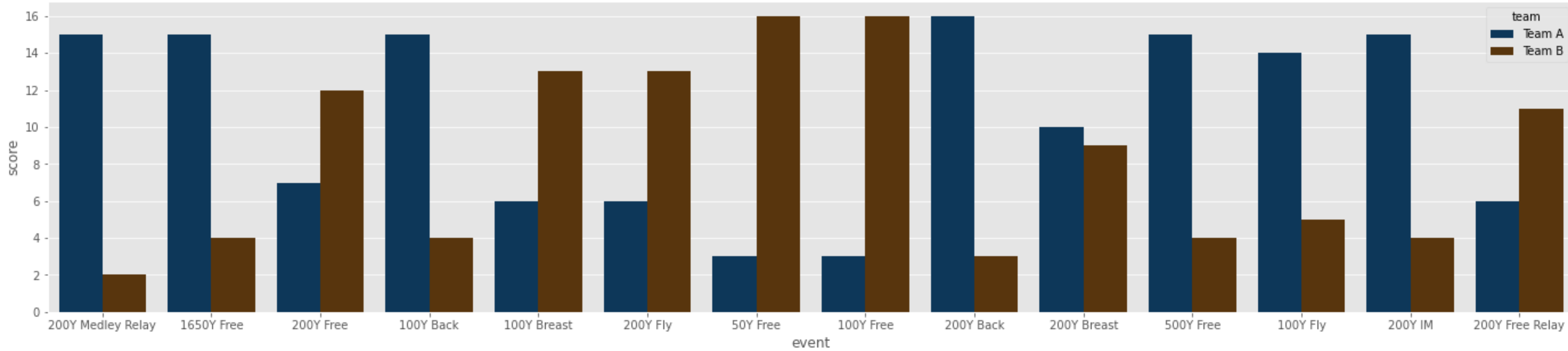
In [ ]:

```
score_A,score_B,eventScore_df_2 = calculate_pred_score(TeamA_Perf_wM_df, TeamA_Lineup_df[1], \
    TeamB_Perf_wM_df, TeamB_Lineup_df[0], scoring_method="Six Lane")

print("Projected scores: \nTeam A: ",score_A,"\nTeam B: ",score_B)
```

```
Projected scores:
Team A:  146.0
Team B:  116.0
```

In [ ]:

```
f, ax = plt.subplots(figsize=(24, 5))

# Set event field as category, reorder to meet order, and rename to user-friendly names
eventScore_df_2.event = eventScore_df_2.event.astype('category')
eventScore_df_2.event = eventScore_df_2.event.cat.reorder_categories(EventScoreOrder)
eventScore_df_2.event = eventScore_df_2.event.cat.rename_categories(EventScoreLabelConvertDict )

sns.barplot(x="event", y="score", hue='team', data=eventScore_df_2, palette=[TeamA_blue, TeamB_brown], ci=None);
```



So our improved lineup results in a forecasted win by 30 points from the previous lineup's forecasted win by 12 points. What does the algorithm say that Team B should do to lineups 0 (base) and optimized (1)? Assume that the opponents lineup is known

Team B recommended response to the base lineup (Team A LU 0):

1. Get opptime for Team A's Base Lineup

In [ ]:

```
# opponents times needs to be in lineup (or scenario), opponent rank (1,2,3,4), then the name of the scored event
TeamA_lineupNums = 1
opptime_TeamA_dict = dict()
for i in range(TeamA_lineupNums):
    opptime_TeamA_dict[i+1] = create_opptime_dict(TeamA_Perf_wM_df, TeamA_Lineup_df[i], BigM)

print(opptime_TeamA_dict[1][3])
```

```
{'M50': 111.17899999999999, 'F50': 268.319, 'F11650Y': 1039.339, 'F1200Y': 114.31899999999999, 'F2100Y': 55.829, 'F3100Y': 68.419, 'F4200Y': 124.419, 'F150
Y': 24.308999999999997, 'F1100Y': 53.059000000000005, 'F2200Y': 120.979, 'F3200Y': 146.289, 'F1500Y': 299.439, 'F4100Y': 55.749, 'F5200Y': 124.529}
```

2. Find the MeetOpt lineup for the base Team A lineup

In [ ]:

```
# Do this for Team_A and then make a new function after getting it to work
# Drop all the peformance columns for B, C, and D relays. They are all identical to the A values
TeamB_Perf_df_MO = TeamB_Perf_wM_df.loc[:,~TeamB_Perf_wM_df.columns.str.endswith(('B','C','D'))]

# List the columns of the predicted performance list
# TeamB_pred_perf_events = TeamB_Perf_df_MO.columns.tolist()
# print(TeamB_pred_perf_events)
```

In [ ]:

```
# Get list of swimmer IDs from Team B
TeamB_swimmers = TeamB_Perf_df_MO.index.values.tolist()
print(TeamB_swimmers)
```

```
[195456, 197178, 213253, 233796, 233836, 256012, 271442, 271492, 273646, 273907, 282290, 291023, 323285, 330114, 330349, 342505, 342630, 342918, 345696, 37
```

```
7792, 403859, 404163, 405026, 411706, 422229, 432465, 494957, 696579]
```

In [ ]:

```python
# Create the Team B dictionary in the right structure
# Convert pandas to dict and use Swimmer as row index and Event as columns
TeamB_Perf_dict = TeamB_Perf_df_MO.to_dict(orient='index')
# Show the values
TeamB_Perf_dict[197178]['FLF50A']
```

Out[ ]:

```
105.96
```

In [ ]:

```python
# For CONSISTENCY:

# Get the number of opponent lineups (scenarios) and their associated probabilities
# These will be generated from game theory later

# Need to use this structre for MeetOpt and to allow for more than one scenario later
# for 3 lineups
# opp_lineup_nums = [1,2,3]
# opp_lineup_num = (.1,.5,.4)
oppA_lineup_nums = [1]
oppA_lineup_select_prob = (1,)

# connect the lineup nums with their associate probs in a dictionary for MeetOpt
oppA_scenario_prob = dict(zip(oppA_lineup_nums,oppA_lineup_select_prob))

print(oppA_scenario_prob)
```

```
{1: 1}
```

In [ ]:

```python
# Find MeetOpt response for Team B to the base for Team A (LU 0)
TeamB_Lineup_df[1],_,_ = MeetOpt(TeamB_swimmers, oppA_lineup_nums, oppA_scenario_prob, individual_scored_events, \
    relay_scored_events, relay_noMR, MR_legs,relay_pastperf_events,Lineup_Events,TeamB_Perf_dict,opptime_TeamA_dict, BigM)

# Reorder the columns to the meet event order
TeamB_Lineup_df[1] = TeamB_Lineup_df[1][EventOrder]
```

```
NOW WE'RE IN MEETOPT:

event_noMR:  ('F1200Y', 'F150Y', 'F1100Y', 'F4100Y', 'F2100Y', 'F2200Y', 'F1500Y', 'F5200Y', 'F3100Y', 'F4200Y', 'F3200Y', 'F11650Y', 'F50')
{1: 1}
total SCORED events:  ('F1200Y', 'F150Y', 'F1100Y', 'F4100Y', 'F2100Y', 'F2200Y', 'F1500Y', 'F5200Y', 'F3100Y', 'F4200Y', 'F3200Y', 'F11650Y', 'M50', 'F5
0')
total PERF events:  ('F1200Y', 'F150Y', 'F1100Y', 'F4100Y', 'F2100Y', 'F2200Y', 'F1500Y', 'F5200Y', 'F3100Y', 'F4200Y', 'F3200Y', 'F11650Y', 'FLM50A', 'F2M
50A', 'F3M50A', 'F4M50A', 'FLF50A', 'F1F50A')
total ASSIGNED events: ('F1200Y', 'F150Y', 'F1100Y', 'F4100Y', 'F2100Y', 'F2200Y', 'F1500Y', 'F5200Y', 'F3100Y', 'F4200Y', 'F3200Y', 'F11650Y', 'FLM50A',
'F2M50A', 'F3M50A', 'F4M50A', 'FLM50B', 'F2M50B', 'F3M50B', 'F4M50B', 'FLM50C', 'F2M50C', 'F3M50C', 'F4M50C', 'FLM50D', 'F2M50D', 'F3M50D', 'F4M50D', 'FLF5
0A', 'F1F50A', 'FLF50B', 'F1F50B', 'FLF50C', 'F1F50C', 'FLF50D', 'F1F50D')
Check Done
obj done
Total Setup Time =  0  secs
Solve the baseline problem:
Gurobi Optimizer version 9.5.1 build v9.5.1rc2 (win64)
Thread count: 4 physical cores, 8 logical processors, using up to 8 threads
Optimize a model with 994 rows, 1765 columns and 9057 nonzeros
```

```
Model fingerprint: 0xfafe8554
Variable types: 43 continuous, 1722 integer (0 binary)
Coefficient statistics:
  Matrix range     [1e-03, 4e+03]
  Objective range  [1e+00, 1e+00]
  Bounds range     [1e+00, 1e+00]
  RHS range        [1e+00, 4e+03]
Presolve removed 331 rows and 95 columns
Presolve time: 0.04s
Presolved: 663 rows, 1670 columns, 7661 nonzeros
Variable types: 0 continuous, 1670 integer (1628 binary)

Root relaxation: objective 1.579464e+02, 330 iterations, 0.01 seconds (0.00 work units)

    Nodes    |    Current Node    |     Objective Bounds      |     Work
 Expl Unexpl |  Obj  Depth IntInf | Incumbent    BestBd   Gap | It/Node Time

     0     0 157.93524    0   73          - 157.93524      -     -    0s
     0     0 141.87825    0  111          - 141.87825      -     -    0s
     0     0 138.89824    0   92          - 138.89824      -     -    0s
     0     0 138.89824    0   93          - 138.89824      -     -    0s
     0     0 132.95296    0   78          - 132.95296      -     -    0s
H    0     0                     117.0000000  132.91050  13.6%     -    0s
     0     0 132.91050    0   67  117.00000  132.91050  13.6%     -    0s
H    0     0                     123.0000000  132.91050  8.06%     -    0s
     0     0 132.85034    0   56  123.00000  132.85034  8.01%     -    0s
     0     0 132.00000    0   34  123.00000  132.00000  7.32%     -    0s
H    0     0                     132.0000000  132.00000  0.00%     -    0s
     0     0 132.00000    0   34  132.00000  132.00000  0.00%     -    0s

Cutting planes:
  Gomory: 4
  Cover: 27
  Clique: 14
  MIR: 10
  StrongCG: 2
  GUB cover: 40
  RLT: 8
  Relax-and-lift: 12

Explored 1 nodes (1298 simplex iterations) in 0.34 seconds (0.08 work units)
Thread count was 8 (of 8 available processors)

Solution count 3: 132 123 117

Optimal solution found (tolerance 1.00e-04)
Best objective 1.320000000000e+02, best bound 1.320000000000e+02, gap 0.0000%
Gurobi status= 2
 Total Solve Time =  0  mins
 Status: Optimal
 Objective: 132.0  points
 Best Found Solution Objective=  132.0
 Score under Scenario  1 is  132
```

In [ ]:

```
# Clean up the output (-0.0) by making all integers
TeamB_Lineup_df[1] = TeamB_Lineup_df[1][TeamB_Lineup_df[1].columns].astype('int8')
```

MeetOpt creates a lineup with an expected score of 132 points for Team B vs. the base lineup from Team A. Recall that with Team B's base lineup (vs. Team A's base lineup) we projected (and in reality it matched) a score of 137-125. To account for the tie rules, what is the better prediction from these two lineups?

In [ ]:

```
score_A,score_B,eventScore_df_3 = calculate_pred_score(TeamA_Perf_wM_df, TeamA_Lineup_df[0], \
    TeamB_Perf_wM_df, TeamB_Lineup_df[1], scoring_method="Six Lane")

print("Projected scores: \nTeam A: ",score_A,"\nTeam B: ",score_B,"\nDiff: ", score_A-score_B)
```

```
Projected scores:
Team A:  130.0
Team B:  132.0
Diff:  -2.0
```

What if each team used the MeetOpt lineups vs each other?

In [ ]:

```
score_A,score_B,eventScore_df_4 = calculate_pred_score(TeamA_Perf_wM_df, TeamA_Lineup_df[1], \
    TeamB_Perf_wM_df, TeamB_Lineup_df[1], scoring_method="Six Lane")

print("Projected scores: \nTeam A: ",score_A,"\nTeam B: ",score_B,"\nDiff: ", score_A-score_B)
```

```
Projected scores:
Team A:  144
Team B:  118
Diff:  26
```

GAME THEORY: What if these were the only two lineups they could use? What would be the best response?

First create a function to solve a game theory matrix

In [ ]:

```
from gurobipy import *

def FindOptStrategy(team, payoffmatrix):
    try:
        # Create variables
        numrows = len(payoffmatrix)    # payoff matrix number of rows
        numcols = len(payoffmatrix[0]) # payoff matrix number of columns

        if team == "B":
            # Create a new model
            optModelB = Model("TeamBStrategy")
            optModelB.reset()

            #optModelB.setParam('Presolve',0)

            g = optModelB.addVars(numcols, lb= 0.0, ub=GRB.INFINITY, vtype=GRB.CONTINUOUS, name="g")
            u = optModelB.addVar(lb=-GRB.INFINITY, ub=GRB.INFINITY, vtype=GRB.CONTINUOUS,name="u")

            # Set objective
```

```
            optModelB.setObjective(u, GRB.MINIMIZE)

            # Add constraint: sumproduct down rows <= bound u.
            optModelB.addConstrs((quicksum(payoffmatrix[i][j]*g[j] for j in range(numcols)) <= u for i in range(numrows)),"bounds")

            # Add constraint: sum of f  = 1, well defined distribution
            optModelB.addConstr(quicksum(g[i] for i in range(numcols)) == 1, "c1")

            optModelB.optimize()
            print (optModelB.display())

            policy, value = printSolution(optModelB)

        elif team == "A":
            # Create a new model
            optModelA = Model("TeamAStrategy")
            optModelA.reset()

            #optModelA.setParam('Presolve',0)

            f = optModelA.addVars(numrows, lb=0.0, ub=GRB.INFINITY, vtype=GRB.CONTINUOUS, name="f")
            v = optModelA.addVar(lb=-GRB.INFINITY, ub=GRB.INFINITY, vtype=GRB.CONTINUOUS,name="v")

            # Set objective
            optModelA.setObjective(v, GRB.MAXIMIZE)

            # Add constraint: sumproduct down rows <= bound u.
            optModelA.addConstrs((quicksum(payoffmatrix[i][j]*f[i] for i in range(numrows)) >= v for j in range(numcols)),"bounds")

            # Add constraint: sum of f  = 1, well-defined distribution
            optModelA.addConstr(quicksum(f[i] for i in range(numrows)) == 1, "c2")

            optModelA.optimize()
            print (optModelA.display())

            policy, value = printSolution(optModelA)

        return policy, value

    except GurobiError as e:
        print('Error code ' + str(e.errno) + ": " + str(e))

    except AttributeError:
        print('Encountered an attribute error')

def printSolution(m):
    answer_dic = {}

    for var in m.getVars():
        print('%s %g' % (var.varName, var.x))
        answer_dic.update({var.varName : var.x})

    print('Obj: %g' % m.objVal)

    #return the variables and their optimal values
    return answer_dic, m.objVal
```

Use model to find the optimal strategy for each team

In [ ]:

```
# Create the score matrix with Team
LineupA0vB0 = 12
LineupA0vB1 = -2
LineupA1vB0 = 30
LineupA1vB1 = 30

score_matrix = [[LineupA0vB0 ,LineupA0vB1], [LineupA1vB0,LineupA1vB1]]

#Return the Nash equilibrium mixed strategy and expected points for team A and team B.
f,optB = FindOptStrategy('A', score_matrix)
g,optA = FindOptStrategy('B', score_matrix)

print('\n Printing f: ',f)
print('\n Printing optA: ', optA)
print('\n Printing g: ', g)
print('\n Printing optB: ',optB)
```

```
Discarded solution information
Gurobi Optimizer version 9.5.1 build v9.5.1rc2 (win64)
Thread count: 4 physical cores, 8 logical processors, using up to 8 threads
Optimize a model with 3 rows, 3 columns and 8 nonzeros
Model fingerprint: 0x093028a7
Coefficient statistics:
  Matrix range     [1e+00, 3e+01]
  Objective range  [1e+00, 1e+00]
  Bounds range     [0e+00, 0e+00]
  RHS range        [1e+00, 1e+00]
Presolve removed 3 rows and 3 columns
Presolve time: 0.01s
Presolve: All rows and columns removed
Iteration    Objective       Primal Inf.    Dual Inf.      Time
       0    3.0000000e+01   0.000000e+00   0.000000e+00      0s

Solved in 0 iterations and 0.01 seconds (0.00 work units)
Optimal objective  3.000000000e+01
Maximize
  <gurobi.LinExpr: v>
Subject To
  bounds[0]: <gurobi.LinExpr: 12.0 f[0] + 30.0 f[1] + -1.0 v> >= 0
  bounds[1]: <gurobi.LinExpr: -2.0 f[0] + 30.0 f[1] + -1.0 v> >= 0
  c2: <gurobi.LinExpr: f[0] + f[1]> = 1
Bounds
  v free
None
f[0] 0
f[1] 1
v 30
Obj: 30
Discarded solution information
Gurobi Optimizer version 9.5.1 build v9.5.1rc2 (win64)
Thread count: 4 physical cores, 8 logical processors, using up to 8 threads
Optimize a model with 3 rows, 3 columns and 8 nonzeros
```

```
Model fingerprint: 0xe002b602
Coefficient statistics:
  Matrix range     [1e+00, 3e+01]
  Objective range  [1e+00, 1e+00]
  Bounds range     [0e+00, 0e+00]
  RHS range        [1e+00, 1e+00]
Presolve removed 3 rows and 3 columns
Presolve time: 0.01s
Presolve: All rows and columns removed
Iteration    Objective       Primal Inf.    Dual Inf.      Time
       0    3.0000000e+01   0.000000e+00   0.000000e+00      0s

Solved in 0 iterations and 0.01 seconds (0.00 work units)
Optimal objective  3.000000000e+01
Minimize
  <gurobi.LinExpr: u>
Subject To
  bounds[0]: <gurobi.LinExpr: 12.0 g[0] + -2.0 g[1] + -1.0 u> <= 0
  bounds[1]: <gurobi.LinExpr: 30.0 g[0] + 30.0 g[1] + -1.0 u> <= 0
  c1: <gurobi.LinExpr: g[0] + g[1]> = 1
Bounds
  u free
None
g[0] 1
g[1] 0
u 30
Obj: 30

 Printing f:  {'f[0]': 0.0, 'f[1]': 1.0, 'v': 30.0}

 Printing optA:  30.0

 Printing g:  {'g[0]': 1.0, 'g[1]': 0.0, 'u': 30.0}

 Printing optB:  30.0
```

Display the Payoff Matrix for all four lineup pairs

In [ ]:

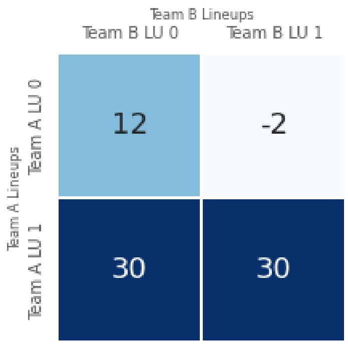
```python
#from tabulate import tabulate
from IPython.display import display, HTML

payoff_df = pd.DataFrame({"Team B LU 0": [LineupA0vB0, LineupA1vB0], "Team B LU 1": [LineupA0vB1, LineupA1vB1]}, index=['Team A LU 0', 'Team A LU 1'])
display(HTML(payoff_df.to_html()))
#df.to_latex()
```

	Team B LU 0	Team B LU 1
Team A LU 0	12	-2
Team A LU 1	30	30

In [ ]:

```python
# Displaying dataframe as an heatmap
fig, axs = plt.subplots(1, 1, figsize=(3, 3), constrained_layout=True)
```

```
sns.heatmap(payoff_df, linewidths = 0.3, annot = True,
            annot_kws={"size": 18},cbar= False, square= True, cmap= 'Blues')


#clean up the charts
#fig.suptitle('Lineup Payoff Matrix')
axs.set_ylabel('Team A Lineups',fontsize='small')
axs.set_xlabel('Team B Lineups', fontsize='small')

axs.xaxis.tick_top()
axs.tick_params(left=False, top=False) ## other options are right and top
axs.xaxis.set_label_position('top')

plt.show()
```



FIX WORDING: The Nash Equilibrium is for both teams to use their respective lineups 1. Where Lehigh will lose by 25 points. These lineups (created by MeetOpt) are in response to the other team using LU 0, so a better lineup in response to LU 1 may also exist leading to a 3x3 strategy. Alternatively, you could create a lineup in response to the other team being equally likely to choose one of the other lineups.

Let's extend this one more step by adding optimal responses to opponents LU 1s.

Team A's response to Team B's LU 1:

1. Get opptime for Team B's LU 1:

In [ ]:

```
# opponents times needs to be in lineup (or scenario), opponent rank (1,2,3,4), then the name of the scored event
TeamB_lineupNums = 1
opptime_TeamB_dict = dict()
for i in range(TeamB_lineupNums):
    # Doing this for LU 1 for Team B
    opptime_TeamB_dict[i+1] = create_opptime_dict(TeamB_Perf_wM_df, TeamB_Lineup_df[1], BigM)

print(opptime_TeamB_dict[1][3])
```

```
{'M50': 481.319, 'F50': 443.279, 'F11650Y': 1099.049, 'F1200Y': 112.639, 'F2100Y': 252.19899999999998, 'F3100Y': 66.919, 'F4200Y': 1589.039, 'F150Y': 23.81
9, 'F1100Y': 51.499, 'F2200Y': 130.599, 'F3200Y': 143.049, 'F1500Y': 307.529, 'F4100Y': 61.169000000000004, 'F5200Y': 139.599}
```

2. Find the MeetOpt response to Team B LU 1

In [ ]:

```
# def MeetOpt(athleteFull,scenario,scenprob,indiv_events,relay_scored_events,relaynoMR,stroke,relay_pastperf_events,lineup_events, playperf,opptime):

# Find MeetOpt response lineup to the base
TeamA_Lineup_df[2],r,w = MeetOpt(TeamA_swimmers, oppB_lineup_nums, oppB_scenario_prob, individual_scored_events, \
    relay_scored_events, relay_noMR, MR_legs,relay_pastperf_events,Lineup_Events,TeamA_Perf_dict,opptime_TeamB_dict,BigM)

# Reorder the columns to the meet event order
TeamA_Lineup_df[2] = TeamA_Lineup_df[2][EventOrder]
```

```
NOW WE'RE IN MEETOPT:

event_noMR:  ('F1200Y', 'F150Y', 'F1100Y', 'F4100Y', 'F2100Y', 'F2200Y', 'F1500Y', 'F5200Y', 'F3100Y', 'F4200Y', 'F3200Y', 'F11650Y', 'F50')
{1: 1}
total SCORED events:  ('F1200Y', 'F150Y', 'F1100Y', 'F4100Y', 'F2100Y', 'F2200Y', 'F1500Y', 'F5200Y', 'F3100Y', 'F4200Y', 'F3200Y', 'F11650Y', 'M50', 'F5
0')
total PERF events:  ('F1200Y', 'F150Y', 'F1100Y', 'F4100Y', 'F2100Y', 'F2200Y', 'F1500Y', 'F5200Y', 'F3100Y', 'F4200Y', 'F3200Y', 'F11650Y', 'FLM50A', 'F2M
50A', 'F3M50A', 'F4M50A', 'FLF50A', 'F1F50A')
total ASSIGNED events: ('F1200Y', 'F150Y', 'F1100Y', 'F4100Y', 'F2100Y', 'F2200Y', 'F1500Y', 'F5200Y', 'F3100Y', 'F4200Y', 'F3200Y', 'F11650Y', 'FLM50A',
'F2M50A', 'F3M50A', 'F4M50A', 'FLM50B', 'F2M50B', 'F3M50B', 'F4M50B', 'FLM50C', 'F2M50C', 'F3M50C', 'F4M50C', 'FLM50D', 'F2M50D', 'F3M50D', 'F4M50D', 'FLF5
0A', 'F1F50A', 'FLF50B', 'F1F50B', 'FLF50C', 'F1F50C', 'FLF50D', 'F1F50D')
Check Done
obj done
Total Setup Time =  0  secs
Solve the baseline problem:
Gurobi Optimizer version 9.5.1 build v9.5.1rc2 (win64)
Thread count: 4 physical cores, 8 logical processors, using up to 8 threads
Optimize a model with 960 rows, 1657 columns and 8493 nonzeros
Model fingerprint: 0x227c8b80
Variable types: 43 continuous, 1614 integer (0 binary)
Coefficient statistics:
  Matrix range     [1e-03, 4e+03]
  Objective range  [1e+00, 1e+00]
  Bounds range     [1e+00, 1e+00]
  RHS range        [1e+00, 4e+03]
Presolve removed 319 rows and 95 columns
Presolve time: 0.02s
Presolved: 641 rows, 1562 columns, 7202 nonzeros
Variable types: 0 continuous, 1562 integer (1520 binary)

Root relaxation: objective 1.779294e+02, 394 iterations, 0.01 seconds (0.00 work units)

    Nodes    |    Current Node    |     Objective Bounds      |     Work
 Expl Unexpl |  Obj  Depth IntInf | Incumbent    BestBd   Gap | It/Node Time

     0     0 176.91340    0  105          - 176.91340      -     -    0s
H    0     0                     122.0000000 164.12523  34.5%     -    0s
H    0     0                     129.0000000 164.12523  27.2%     -    0s
     0     0 164.12523    0  119  129.00000 164.12523  27.2%     -    0s
H    0     0                     140.0000000 164.12523  17.2%     -    0s
H    0     0                     144.0000000 164.12212  14.0%     -    0s
     0     0 164.12212    0  118  144.00000 164.12212  14.0%     -    0s
H    0     0                     151.0000000 159.42658  5.58%     -    0s
     0     0 159.42658    0   84  151.00000 159.42658  5.58%     -    0s
```

```
     0     0  159.42357    0   91  151.00000  159.42357  5.58%     -    0s
H    0     0                    152.0000000  159.42357  4.88%     -    0s
     0     0  158.98552    0   58  152.00000  158.98552  4.60%     -    0s
H    0     0                    154.0000000  158.98552  3.24%     -    0s
     0     0  158.00000    0   34  154.00000  158.00000  2.60%     -    0s
     0     0  158.00000    0   24  154.00000  158.00000  2.60%     -    0s
     0     0  158.00000    0   29  154.00000  158.00000  2.60%     -    0s
     0     0  158.00000    0   26  154.00000  158.00000  2.60%     -    0s
     0     0  158.00000    0   28  154.00000  158.00000  2.60%     -    0s
     0     0  158.00000    0   29  154.00000  158.00000  2.60%     -    0s
     0     0  158.00000    0    8  154.00000  158.00000  2.60%     -    0s
H    0     0                    156.0000000  158.00000  1.28%     -    0s
     0     0  158.00000    0   20  156.00000  158.00000  1.28%     -    0s
H    0     0                    158.0000000  158.00000  0.00%     -    0s
     0     0  158.00000    0   17  158.00000  158.00000  0.00%     -    0s

Cutting planes:
  Gomory: 7
  Cover: 45
  Clique: 20
  MIR: 20
  StrongCG: 4
  GUB cover: 47
  Inf proof: 1
  RLT: 10
  Relax-and-lift: 13

Explored 1 nodes (3198 simplex iterations) in 0.61 seconds (0.16 work units)
Thread count was 8 (of 8 available processors)

Solution count 9: 158 156 154 ... 122

Optimal solution found (tolerance 1.00e-04)
Best objective 1.580000000000e+02, best bound 1.580000000000e+02, gap 0.0000%
Gurobi status= 2
 Total Solve Time =  0  mins
 Status: Optimal
 Objective: 158.0  points
 Best Found Solution Objective=  158.0
 Score under Scenario  1 is  158
```

In [ ]:

```
# Clean up the output (-0.0) by making all integers
TeamA_Lineup_df[2] = TeamA_Lineup_df[2][TeamA_Lineup_df[2].columns].astype('int8')
```

In [ ]:

```
#########
# JUST FOR DEBUGGING
indiv_score_dict = {1:9,2:4,3:3,4:2,5:1,6:0}
relay_score_dict = {1:11,2:4,3:2}
```

In [ ]:

```
#########
# JUST FOR DEBUGGING

for ev in ['F11650Y','F1200Y','F2100Y','F3100Y','F4200Y','F150Y','F1100Y','F2200Y','F3200Y','F1500Y','F4100Y','F5200Y']:
```

```
    tot=0
    for p in [1,2,3]:
        if isnan(w.loc[p,ev]):
            point = 0
        else:
            point = indiv_score_dict[w.loc[p,ev]]
            #point = w.loc[p,ev]
        tot = point + tot
    print(ev, " ", tot)

for ev in ['M50','F50']:
    tot=0
    for p in [1,2,3]:
        if isnan(w.loc[p,ev]):
            point = 0
        else:
            point = relay_score_dict[w.loc[p,ev]]
            #point = w.loc[p,ev]
        tot = point + tot
    print(ev, " ", tot)

##########
```

```
F11650Y   15
F1200Y   8
F2100Y   15
F3100Y   6
F4200Y   6
F150Y   4
F1100Y   4
F2200Y   16
F3200Y   10
F1500Y   15
F4100Y   14
F5200Y   15
M50   15
F50   15
```

3. Verify the score would be if these two LUs competed

CHECK: It's not assigning swimmers to events when it can do leave it empty and still get points. Need to make sure that it assigns a person if it can.

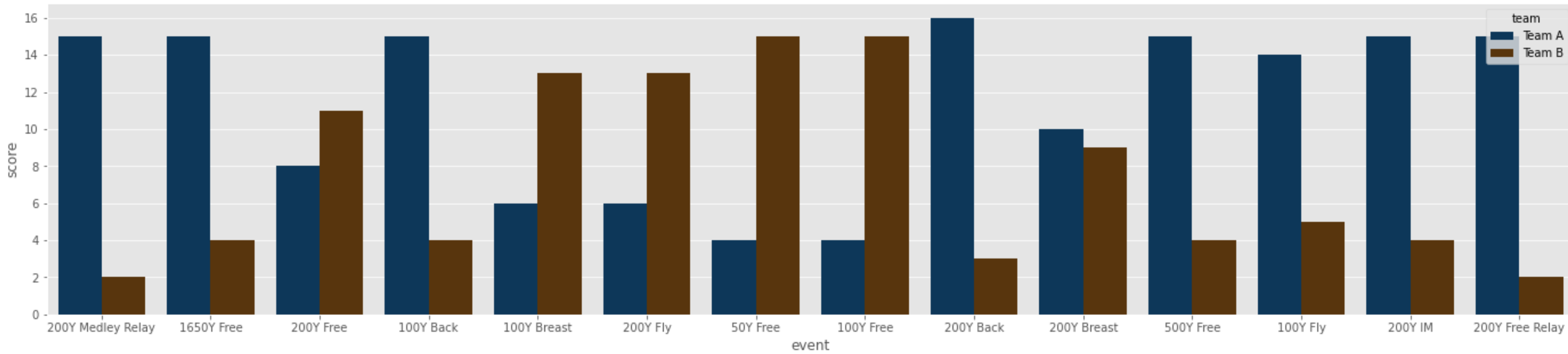
In [ ]:

```
# Which lineups to score in a competition?
TeamA_LU = 2
TeamB_LU = 1

score_A,score_B,eventScore_df_5 = calculate_pred_score(TeamA_Perf_wM_df, TeamA_Lineup_df[TeamA_LU], \
    TeamB_Perf_wM_df, TeamB_Lineup_df[TeamB_LU], scoring_method="Six Lane")

print("Projected scores: \nTeam A: ",score_A,"\nTeam B: ",score_B, "\nDiff: ", score_A-score_B)
```

```
Projected scores: 
Team A:  158
```

```
Team B:  104
Diff:   54
```

In [ ]:
```
# Viz of team scores for Team A LU 2 vs Team B LU 1
ChartScore(eventScore_df_5, TeamA_blue, TeamB_brown,24,5)
```



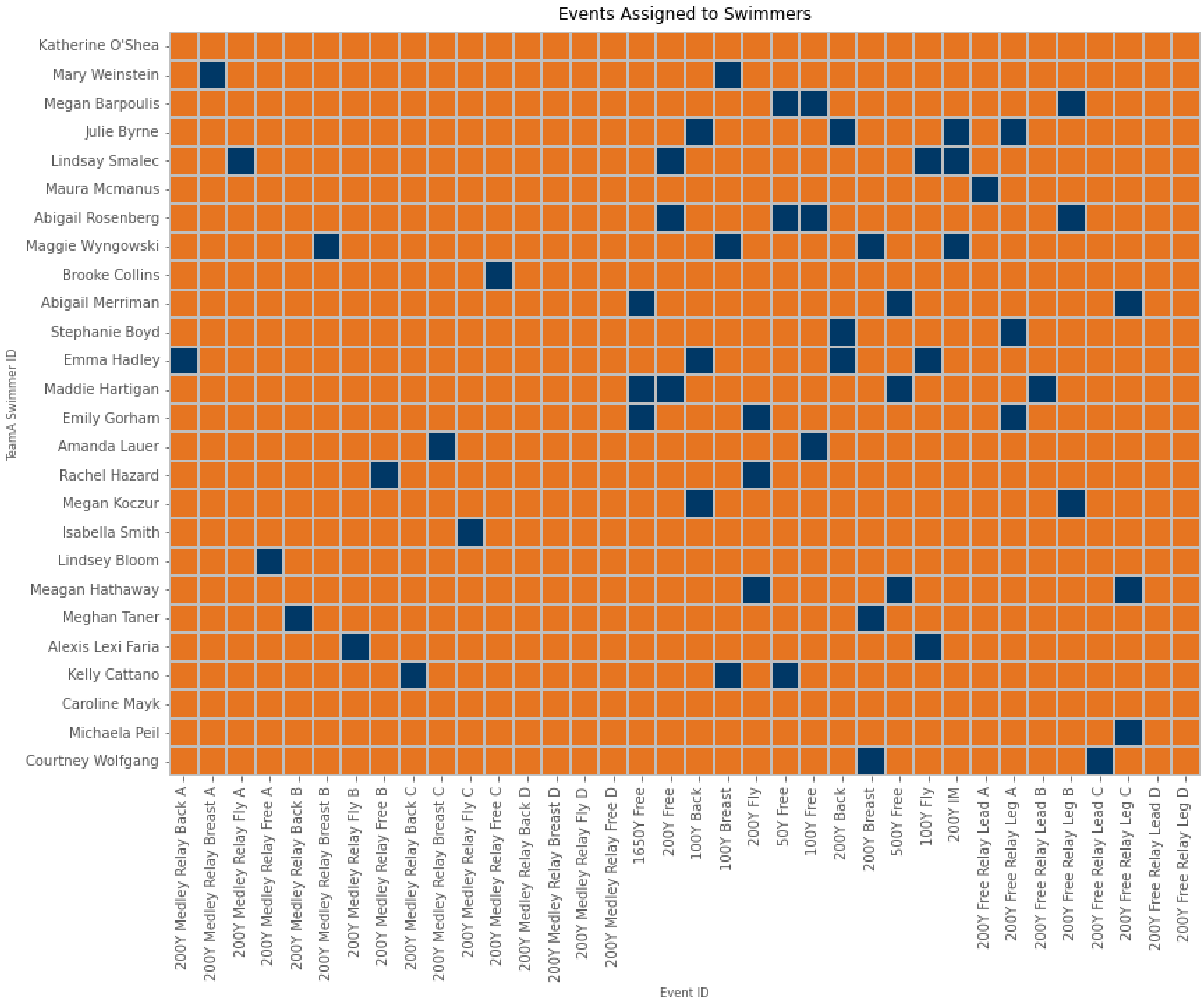
In [ ]:
```
#####
# Debugging Code

print((TeamA_Lineup_df[2]*TeamA_Perf_wM_df)[['FLM50A', 'F2M50A','F3M50A','F4M50A']].max().sum(), "  ",\
    (TeamA_Lineup_df[2]*TeamA_Perf_wM_df)[['FLM50B', 'F2M50B','F3M50B','F4M50B']].max().sum(), "  ", \
    (TeamA_Lineup_df[2]*TeamA_Perf_wM_df)[['FLM50C', 'F2M50C','F3M50C','F4M50C']].max().sum())
```

```
105.16     105.42     394.92999999999995
```

In [ ]:
```
#####
# Debugging Code

print((TeamB_Lineup_df[1]*TeamB_Perf_wM_df)[['FLM50A', 'F2M50A','F3M50A','F4M50A']].max().sum(), "  ",\
    (TeamB_Lineup_df[1]*TeamB_Perf_wM_df)[['FLM50B', 'F2M50B','F3M50B','F4M50B']].max().sum(), "  ", \
    (TeamB_Lineup_df[1]*TeamB_Perf_wM_df)[['FLM50C', 'F2M50C','F3M50C','F4M50C']].max().sum())
```

```
105.47999999999999     106.11     481.32
```

In [ ]:
```
# Viz of Team LU 2
ChartLineup('TeamA', TeamA_colors, TeamA_Lineup_df[2], 18, 10)
```



Team A LU 2 vs Team B LU 1 and Team A wins by 54.

Team B's Response to Team A's LU 1:

1. Get opptime for Team A's LU 1:

In [ ]:

```
# opponents times needs to be in lineup (or scenario), opponent rank (1,2,3,4), then the name of the scored event
TeamA_lineupNums = 1
```

```
opptime_TeamA_dict = dict()
for i in range(TeamA_lineupNums):
    # Doing this for LU 1 for Team A
    opptime_TeamA_dict[i+1] = create_opptime_dict(TeamA_Perf_wM_df, TeamA_Lineup_df[1], BigM)

print(opptime_TeamA_dict[1][3])
```

```
{'M50': 392.04900000000004, 'F50': 443.279, 'F11650Y': 1035.659, 'F1200Y': 503.559, 'F2100Y': 55.829, 'F3100Y': 68.419, 'F4200Y': 124.399, 'F150Y': 24.3089
99999999997, 'F1100Y': 55.929, 'F2200Y': 120.979, 'F3200Y': 154.339, 'F1500Y': 299.439, 'F4100Y': 55.749, 'F5200Y': 126.59899999999999}
```

2. Find the MeetOpt Team B response LU to Team A LU 1

In [ ]:

```
# def MeetOpt(athleteFull,scenario,scenprob,indiv_events,relay_scored_events,relaynoMR,stroke,relay_pastperf_events,lineup_events, playperf,opptime):

# Find MeetOpt response lineup to the base
TeamB_Lineup_df[2],_,_ = MeetOpt(TeamB_swimmers, oppA_lineup_nums, oppA_scenario_prob, individual_scored_events, \
    relay_scored_events, relay_noMR, MR_legs,relay_pastperf_events,Lineup_Events,TeamB_Perf_dict,opptime_TeamA_dict,BigM)

# Reorder the columns to the meet event order
TeamB_Lineup_df[2] = TeamB_Lineup_df[2][EventOrder]
```

```
NOW WE'RE IN MEETOPT:

event_noMR:  ('F1200Y', 'F150Y', 'F1100Y', 'F4100Y', 'F2100Y', 'F2200Y', 'F1500Y', 'F5200Y', 'F3100Y', 'F4200Y', 'F3200Y', 'F11650Y', 'F50')
{1: 1}
total SCORED events:  ('F1200Y', 'F150Y', 'F1100Y', 'F4100Y', 'F2100Y', 'F2200Y', 'F1500Y', 'F5200Y', 'F3100Y', 'F4200Y', 'F3200Y', 'F11650Y', 'M50', 'F5
0')
total PERF events:  ('F1200Y', 'F150Y', 'F1100Y', 'F4100Y', 'F2100Y', 'F2200Y', 'F1500Y', 'F5200Y', 'F3100Y', 'F4200Y', 'F3200Y', 'F11650Y', 'FLM50A', 'F2M
50A', 'F3M50A', 'F4M50A', 'FLF50A', 'F1F50A')
total ASSIGNED events: ('F1200Y', 'F150Y', 'F1100Y', 'F4100Y', 'F2100Y', 'F2200Y', 'F1500Y', 'F5200Y', 'F3100Y', 'F4200Y', 'F3200Y', 'F11650Y', 'FLM50A',
'F2M50A', 'F3M50A', 'F4M50A', 'FLM50B', 'F2M50B', 'F3M50B', 'F4M50B', 'FLM50C', 'F2M50C', 'F3M50C', 'F4M50C', 'FLM50D', 'F2M50D', 'F3M50D', 'F4M50D', 'FLF5
0A', 'F1F50A', 'FLF50B', 'F1F50B', 'FLF50C', 'F1F50C', 'FLF50D', 'F1F50D')
Check Done
obj done
Total Setup Time =  0  secs
Solve the baseline problem:
Gurobi Optimizer version 9.5.1 build v9.5.1rc2 (win64)
Thread count: 4 physical cores, 8 logical processors, using up to 8 threads
Optimize a model with 994 rows, 1765 columns and 9057 nonzeros
Model fingerprint: 0x9ca1c4b7
Variable types: 43 continuous, 1722 integer (0 binary)
Coefficient statistics:
  Matrix range     [1e-03, 4e+03]
  Objective range  [1e+00, 1e+00]
  Bounds range     [1e+00, 1e+00]
  RHS range        [1e+00, 4e+03]
Presolve removed 327 rows and 108 columns
Presolve time: 0.04s
Presolved: 667 rows, 1657 columns, 7626 nonzeros
Variable types: 0 continuous, 1657 integer (1615 binary)

Root relaxation: objective 1.549638e+02, 356 iterations, 0.01 seconds (0.00 work units)

    Nodes    |    Current Node    |     Objective Bounds      |     Work
 Expl Unexpl |  Obj  Depth IntInf | Incumbent    BestBd   Gap | It/Node Time
```

```
     0     0  150.96018    0   71          -  150.96018      -      -    0s
     0     0  137.95756    0  102          -  137.95756      -      -    0s
     0     0  137.95756    0   97          -  137.95756      -      -    0s
     0     0  132.44650    0   94          -  132.44650      -      -    0s
     0     0  132.44098    0   85          -  132.44098      -      -    0s
     0     0  131.00000    0   37          -  131.00000      -      -    0s
     0     0  131.00000    0   30          -  131.00000      -      -    0s
H    0     0                    107.0000000  131.00000  22.4%     -    0s
     0     0  131.00000    0   20  107.00000  131.00000  22.4%     -    0s
H    0     0                    128.0000000  131.00000  2.34%     -    0s
     0     0  131.00000    0   18  128.00000  131.00000  2.34%     -    0s
     0     0  131.00000    0    3  128.00000  131.00000  2.34%     -    0s
H    0     0                    129.0000000  131.00000  1.55%     -    0s
     0     0  131.00000    0   16  129.00000  131.00000  1.55%     -    0s
H    0     0                    130.0000000  131.00000  0.77%     -    0s
     0     0  131.00000    0    6  130.00000  131.00000  0.77%     -    0s
H    0     0                    131.0000000  131.00000  0.00%     -    0s
     0     0  131.00000    0    6  131.00000  131.00000  0.00%     -    0s

Cutting planes:
  Gomory: 3
  Cover: 32
  Clique: 16
  MIR: 12
  StrongCG: 1
  GUB cover: 42
  Inf proof: 1
  Zero half: 2
  RLT: 3
  Relax-and-lift: 9

Explored 1 nodes (1925 simplex iterations) in 0.46 seconds (0.11 work units)
Thread count was 8 (of 8 available processors)

Solution count 5: 131 130 129 ... 107

Optimal solution found (tolerance 1.00e-04)
Best objective 1.310000000000e+02, best bound 1.310000000000e+02, gap 0.0000%
Gurobi status= 2
 Total Solve Time =  0  mins
 Status: Optimal
 Objective: 131.0  points
 Best Found Solution Objective=  131.0
 Score under Scenario  1 is  131
```

3. Verify the score if these two LUs compete.

NEED TO FIX eventScore_df to be a list of dfs!

In [ ]:

```
# Which lineups to score in a competition?
TeamA_LU = 1
TeamB_LU = 2
```

```
score_A,score_B,eventScore_df_6 = calculate_pred_score(TeamA_Perf_wM_df, TeamA_Lineup_df[TeamA_LU], \
    TeamB_Perf_wM_df, TeamB_Lineup_df[TeamB_LU], scoring_method="Six Lane")

print("Projected scores: \nTeam A: ",score_A,"\nTeam B: ",score_B, "\nDiff: ", score_A-score_B)
```

```
Projected scores:
Team A:  131
Team B:  131
Diff:  0
```

Team A LU 1 vs. Team B LU 2 and Team A wins by 8.

In [ ]:

```
# Which lineups to score in a competition?
TeamA_LU = 0
TeamB_LU = 1

score_A,score_B,eventScore_df_6 = calculate_pred_score(TeamA_Perf_wM_df, TeamA_Lineup_df[TeamA_LU], \
    TeamB_Perf_wM_df, TeamB_Lineup_df[TeamB_LU], scoring_method="Six Lane")

print("Projected scores: \nTeam A: ",score_A,"\nTeam B: ",score_B, "\nDifference: ", score_A-score_B)
```

```
Projected scores:
Team A:  130.0
Team B:  132.0
Difference:  -2.0
```

Game Theory 3x3

In [ ]:

```
# Create the score matrix with Team
LineupA0vB0 = 12
LineupA0vB1 = -2
LineupA0vB2 = 16

LineupA1vB0 = 30
LineupA1vB1 = 26
LineupA1vB2 = 0

LineupA2vB0 = 22
LineupA2vB1 = 54
LineupA2vB2 = 24

score_matrix = [[LineupA0vB0, LineupA0vB1, LineupA0vB2], [LineupA1vB0, LineupA1vB1, LineupA1vB2], [LineupA2vB0, LineupA2vB1, LineupA2vB2]]

#Return the Nash equilibrium mixed strategy and expected points for team A and team B.
f,optB = FindOptStrategy('A', score_matrix)
g,optA = FindOptStrategy('B', score_matrix)

print('\n Printing f: ',f)
print('\n Printing optA: ', optA)
print('\n Printing g: ', g)
print('\n Printing optB: ',optB)
```

```
Discarded solution information
Gurobi Optimizer version 9.5.1 build v9.5.1rc2 (win64)
Thread count: 4 physical cores, 8 logical processors, using up to 8 threads
Optimize a model with 4 rows, 4 columns and 14 nonzeros
Model fingerprint: 0xdcca856d
Coefficient statistics:
  Matrix range     [1e+00, 5e+01]
  Objective range  [1e+00, 1e+00]
  Bounds range     [0e+00, 0e+00]
  RHS range        [1e+00, 1e+00]
Presolve removed 1 rows and 0 columns
Presolve time: 0.01s
Presolved: 3 rows, 4 columns, 11 nonzeros

Iteration    Objective       Primal Inf.    Dual Inf.      Time
       0    2.4000000e+01   2.500000e-01   0.000000e+00      0s
       1    2.2500000e+01   0.000000e+00   0.000000e+00      0s

Solved in 1 iterations and 0.01 seconds (0.00 work units)
Optimal objective  2.250000000e+01
Maximize
  <gurobi.LinExpr: v>
Subject To
  bounds[0]: <gurobi.LinExpr: 12.0 f[0] + 30.0 f[1] + 22.0 f[2] + -1.0 v> >= 0
  bounds[1]: <gurobi.LinExpr: -2.0 f[0] + 26.0 f[1] + 54.0 f[2] + -1.0 v> >= 0
  bounds[2]: <gurobi.LinExpr: 16.0 f[0] + 24.0 f[2] + -1.0 v> >= 0
  c2: <gurobi.LinExpr: f[0] + f[1] + f[2]> = 1
Bounds
  v free
None
f[0] 0
f[1] 0.0625
f[2] 0.9375
v 22.5
Obj: 22.5
Discarded solution information
Gurobi Optimizer version 9.5.1 build v9.5.1rc2 (win64)
Thread count: 4 physical cores, 8 logical processors, using up to 8 threads
Optimize a model with 4 rows, 4 columns and 14 nonzeros
Model fingerprint: 0xbeadd041
Coefficient statistics:
  Matrix range     [1e+00, 5e+01]
  Objective range  [1e+00, 1e+00]
  Bounds range     [0e+00, 0e+00]
  RHS range        [1e+00, 1e+00]
Presolve removed 1 rows and 0 columns
Presolve time: 0.01s
Presolved: 3 rows, 4 columns, 11 nonzeros

Iteration    Objective       Primal Inf.    Dual Inf.      Time
       0    0.0000000e+00   5.000000e+00   0.000000e+00      0s
       1    2.2500000e+01   0.000000e+00   0.000000e+00      0s

Solved in 1 iterations and 0.01 seconds (0.00 work units)
Optimal objective  2.250000000e+01
Minimize
```

```
  <gurobi.LinExpr: u>
Subject To
  bounds[0]: <gurobi.LinExpr: 12.0 g[0] + -2.0 g[1] + 16.0 g[2] + -1.0 u> <= 0
  bounds[1]: <gurobi.LinExpr: 30.0 g[0] + 26.0 g[1] + -1.0 u> <= 0
  bounds[2]: <gurobi.LinExpr: 22.0 g[0] + 54.0 g[1] + 24.0 g[2] + -1.0 u> <= 0
  c1: <gurobi.LinExpr: g[0] + g[1] + g[2]> = 1
Bounds
  u free
None
g[0] 0.75
g[1] 0
g[2] 0.25
u 22.5
Obj: 22.5

 Printing f:  {'f[0]': 0.0, 'f[1]': 0.0625, 'f[2]': 0.9375, 'v': 22.5}

 Printing optA:  22.5

 Printing g:  {'g[0]': 0.75, 'g[1]': 0.0, 'g[2]': 0.25, 'u': 22.5}

 Printing optB:  22.5
```

Optimal mixed strategy is for Team A (0,1/16,15/16) for Team B (3/4,0,1/4) with expected score of Team A winning by 24.5 points on average.

In [ ]:

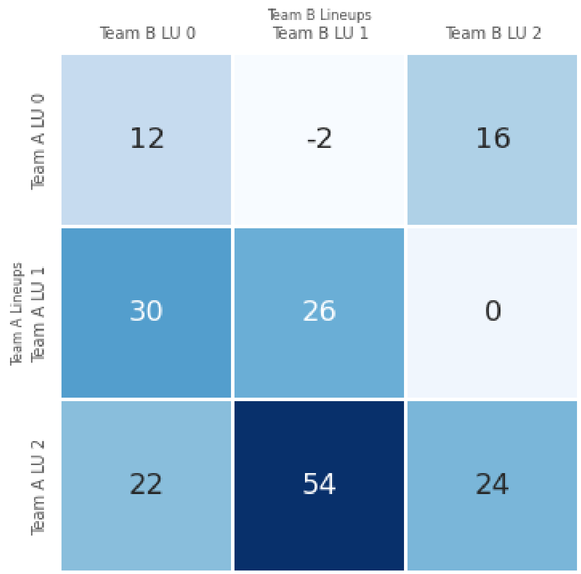
```
payoff3x3_df = pd.DataFrame({"Team B LU 0": [LineupA0vB0, LineupA1vB0, LineupA2vB0], "Team B LU 1": [LineupA0vB1, LineupA1vB1, LineupA2vB1], "Team B LU 2":
display(HTML(payoff3x3_df.to_html()))
#df.to_latex()
```

	Team B LU 0	Team B LU 1	Team B LU 2
Team A LU 0	12	-2	16
Team A LU 1	30	26	0
Team A LU 2	22	54	24

In [ ]:

```
# Displaying dataframe as an heatmap
fig, axs = plt.subplots(1, 1, figsize=(5, 5), constrained_layout=True)

sns.heatmap(payoff3x3_df, linewidths = 0.3, annot = True,
            annot_kws={"size": 18},cbar= False, square= True, cmap= 'Blues')


#clean up the charts
#fig.suptitle('Lineup Payoff Matrix')
axs.set_ylabel('Team A Lineups',fontsize='small')
axs.set_xlabel('Team B Lineups', fontsize='small')

axs.xaxis.tick_top()
axs.tick_params(left=False, top=False) ## other options are right and top
axs.xaxis.set_label_position('top')
```

```
plt.show()
```



Determining the Swimmer Meet Impact (SMI) for a given opponent and lineup (later: distribution of opponent lineups). The SMI for a swimmer can never be more than the total expected points the swimmer is projected to receive versus an opponent, but it can be as low as zero if an adjusted lineup exists where swimmers can be shuffled to still acheive all the points lost by the removed swimmer. Therefore, this is the "impact" of that swimmer with respect to the current opponent and projected performance times.

Create a MeetOpt version where a swimmer (and events can be restricted from the optimization)

In [ ]:

```
#Import PuLP modeller functions
from math import *
import pulp as pl
import time
import os

"""
Created on Sat Jan 12 09:14:40 2019

@author: mdb025
"""

def MeetOptwSMI(athleteFull,scenario,scenprob,indiv_events,relay_scored_events,relaynoMR,stroke,relay_pastperf_events,lineup_events, playperf,opptime, SMI_
    """
    :param athletFull: list of athlete IDs
    :param scenario: integer list of the opponent lineups, e.g. [1, 2]
```

```
:param scenprob: dictionary of scenarios to probability (or weight) of selection. This will be the
the likelihood that the lineup is chosen from a game theory distribution.
:param indiv_scored_events: a list of the names of the events that are scored in a meet for the individuals
:param relaynoMR: the list of names of scored freestyle relay events (no medleys)
:param stroke: the list of names of the legs of the medley relay
:param relay_scored_events: names of relay events scored and in opptime
:param lineup_events: the events list that need to be returned for Team A includes relays A,B,C data from xvar, yvar, zvar.
:param playperf: the dictionary of predicted performances for Team A athletes in each event. indexed by (indiv_scored_events and relay_past_perf_events
:param opptime: the dictionary of opposing team ranked performances. Indexed by scenario (lineup), rank (1,2,3,4,5), events (indiv_scored_events and re

:param: SMI_athlete: the string code of the athlete to restrict from an event (or all events)
:param: SMI_event: A list of events for which the athlete is restricted from participating (use specific code or 'M50' 'F50' for relays)
        or 'All' if restricted from all events to get the event independent SMI, e.g ['M50', 'All', 'F150Y']

#returns optimal response line up to the given opponent lineup(s) (called scenarios)

"""

# Assumes there are enough athletes to field a full team

print("NOW WE'RE IN MEETOPT with SMI: \n")


## Begin INPUT SETTINGS
# 1 if want to write output to file at the following path
# WriteOutput = 0
# path of the output file adjust for user
# if WriteOutput == 1:
#    path = "G:\My Drive\SwimMeetOpt" + "\SwimMeetOptTrialResults.csv"

# Used for comparison
tot_scored_events = indiv_events + relay_scored_events
tot_pastperf_events = indiv_events + relay_pastperf_events
tot_assgn_events = lineup_events
relay = relay_scored_events

#tuples for dictionaries
event_noMR = indiv_events + relaynoMR
print("event_noMR: ", event_noMR)
print(scenprob)
print("total SCORED events: ", tot_scored_events)
print("total PERF events: ", tot_pastperf_events)
print("total ASSIGNED events:", lineup_events)

homerank = (1,2,3)
place = (1,2,3,4,5,6)
ind_points = (9, 4, 3, 2, 1, 0)
relay_points = (11,4,2,0,0,0)
indivplcscore = dict(zip(place,ind_points))
relayplcscore = dict(zip(place,relay_points))

indiv = indiv_events

#Do these exist in college?
Maxevent = 4
Maxrelayevent = 1
```

```python
Maxindevent = 3

TopopprankIndiv = 5
TopopprankRelay = 3


#Set solve time limit in seconds and optimality gap
MaxSolveTime = 10
SolverTimeLimit = MaxSolveTime*60
OptGap = 0.01
#Which Solver?
SolverUsed = "Gurobi"
#SolverUsed = "Gurobi"

if SolverUsed == "CBC":
    #Choose solver, and set it to problem, and build the model
    #Solve with CBC with logging and time limit. Parameter option: keepFiles=1 breaks it!
    #solver = pl.COIN_CMD(msg=1, keepFiles=1, presolve=0, threads=1, maxSeconds=SolverTimeLimit,fracGap = OptGap)
    #solver = pulp.COIN_CMD(msg=1, keepFiles=1, presolve=1, maxSeconds=SolverTimeLimit,fracGap=OptGap)
    pl.PULP_CBC_CMD()
else:
    #Solve with Gurobi
    #solver = pulp.GUROBI_CMD(keepFiles=1,options=[("MIPFocus",1),("TimeLimit",SolverTimeLimit)])
    #solver = pl.GUROBI_CMD(keepFiles=1,options=[("MIPFocus",1),("MIPGap",OptGap),("TimeLimit",SolverTimeLimit)])
    solver = pl.GUROBI()
    #Solve with Cplex. Throws error for write sol file
    #solver = pulp.CPLEX_scCMD(msg=1,options = ['set mip tolerances mipgap 0.2'])
    #solver = pulp.CPLEX_CMD(msg=1,timelimit=30)


#highest relative rank for home
Tophomerank = 3;
# small constant
EPS = 0.0001;
#number of people on a relay team
relaySize = 4;

#subset of the actual athletes with some
#ghosts because of hard relay requirements
#realathlete are only the actual athletes
# ActAthNum = len(athleteFull)
# athlete = athleteFull[:int(ActAthNum)+4]
#realathlete = athleteFull[:int(ActAthNum)]
athlete = athleteFull
# for i in realathlete:
#      print("current realathlete index ", realathlete[realathlete.index(i)])
#      print("previous athlete ", realathlete[realathlete.index(i)-1])

#OUTPUT Arrays and Variables

#Start the clock for first setup
setupStart = time.time()

print("Check Done")

#Instantiate our problem class
```

```python
SwimMeetOpt = pl.LpProblem("MeetMax", pl.LpMaximize)

#Initialize the decision variables
#Scenario scores vs. opps
scenscorevars = {}
# if assigned athlete has 1st time in event
xvars = {}
# if assigned athlete has 2nd best time in event
yvars = {}
# if assigned athlete has 3rd best time in event
zvars = {}
# if assigned athlete has 1st time in start time in event 200MR
xvarleads = {}
# if assigned athlete has 2nd best time in start time in event 200MR
yvarleads = {}
# if assigned athlete has 3rd best time in start time in event 200MR
zvarleads = {}
# if assigned athlete has 1st time in medley
xMRvars = {}
# if assigned athlete has 2nd best time in medley
yMRvars = {}
# if assigned athlete has 3rd best time in medley
zMRvars = {}
# rank of our athletes assigned to events
rvars = {}
#indicator variables of for outcome of event j versus opp 1
wvars = {}
#assignments
asgnvars = {}

#OPTIMIZATION DECISION VARIABLES defined in the MeetOpt paper using PuLP:

#scenscorevar is a placeholder which will hold the expected score of our optimal
#lineup against the lineup given in scenario i
scenscorevar = pl.LpVariable.dicts('scenscorevar',(scenario),0,None,pl.LpContinuous)

#these are placement variables for our athletes to events
#xvar will hold the best assigned athlete from our team in an event
#yvar will hold the second best assigned athlete from our team in an event
#zvar will hold the third best assigned athlete from our team in an event
#We assume that exactly three athletes are assigned to each event
#the optimization creates the assignment and the ordering
xvar = pl.LpVariable.dicts('xvar',(athlete,indiv),0,1,pl.LpBinary)
yvar = pl.LpVariable.dicts('yvar',(athlete,indiv),0,1,pl.LpBinary)
zvar = pl.LpVariable.dicts('zvar',(athlete,indiv),0,1,pl.LpBinary)


#Same as above, but the starting leg for the "non-Medley freestyle Relay" relays
xFRvarlead = pl.LpVariable.dicts('xFRvarlead',(athlete,relaynoMR),0,1,pl.LpBinary)
yFRvarlead = pl.LpVariable.dicts('yFRvarlead',(athlete,relaynoMR),0,1,pl.LpBinary)
zFRvarlead = pl.LpVariable.dicts('zFRvarlead',(athlete,relaynoMR),0,1,pl.LpBinary)

#Same ordering as above, but for the athletes assigned to the
#best, second best, and third best LEGS of Freestyle relay
xFRvar = pl.LpVariable.dicts('xFRvar',(athlete, relaynoMR),0,1,pl.LpBinary)
yFRvar = pl.LpVariable.dicts('yFRvar',(athlete, relaynoMR),0,1,pl.LpBinary)
```

```python
zFRvar = pl.LpVariable.dicts('zFRvar',(athlete, relaynoMR),0,1,pl.LpBinary)

#Same ordering as above, but for the athletes assigned to the
#best, second best, and third best medley relay
xMRvar = pl.LpVariable.dicts('xMRvar',(athlete, stroke),0,1,pl.LpBinary)
yMRvar = pl.LpVariable.dicts('yMRvar',(athlete, stroke),0,1,pl.LpBinary)
zMRvar = pl.LpVariable.dicts('zMRvar',(athlete, stroke),0,1,pl.LpBinary)

#rvar will hold the TIME of our first, second, and third fastest entrants in each event
rvar = pl.LpVariable.dicts('rvar',(homerank,tot_scored_events),None,None,pl.LpContinuous)
#wvar will be 1 if our athlete with homerank h, in event j, finishes in overall place k, against
#opponent scenario l
#with this we can answer in which place our assigned athletes actually finish and score the meet!
wvar = pl.LpVariable.dicts('wvar',(tot_scored_events,homerank, place, scenario),0,1,pl.LpBinary)
#asgnvar is a generic variable which will be 1 if athlete i is assigned to event j (ignoring rank, etc.)
#just answers the question "Is this athlete doing in this event?"
#asgnvar = pl.LpVariable.dicts('asgnvar',(athlete,tot_assgn_events),0,1,pl.LpBinary)


#Objective Function - Maximize the weighted scenario (or expected) score against
#over eact scenario (or against each team)
SwimMeetOpt += pl.lpSum(scenprob[s]*scenscorevar[s] for s in scenario), "Total Expected Score"
print("obj done")

# Multiple relay teams and they cannot sweep so only the top two relay teams are included in the home team score
# defines the variable scenscorevar (scenario score variable) for each scenario
for s in scenario:
    SwimMeetOpt += scenscorevar[s] == pl.lpSum(indivplcscore[p]*wvar[j][k][p][s] for j in indiv for k in homerank for p in place if k<=p) + \
        pl.lpSum(relayplcscore[p]*wvar[j][k][p][s] for j in relay_scored_events for k in homerank for p in place if k<=p) + \
        pl.lpSum(2*wvar[j][1][4][s] - 2*wvar[j][3][3][s] for j in relay_scored_events), "Scenario %s Score"%s


#CREATING THE CONSTRAINTS FOR THE OPTIMIZATION PROBLEM:

# Exactly one 1st, 2nd, 3rd best time athlete in each indiv event
# WARNING: ASSUMES you have sufficent swimmers to meet all the events and relays with max requirements
for j in indiv:
    SwimMeetOpt += pl.lpSum(xvar[i][j] for i in athlete)  == 1, "Exactly one 1st for indiv event %s"%j
    SwimMeetOpt += pl.lpSum(yvar[i][j] for i in athlete)  == 1, "Exactly one 2nd for indiv event %s"%j
    SwimMeetOpt += pl.lpSum(zvar[i][j] for i in athlete)  == 1, "Exactly one 3rd for indiv event %s"%j

# Exactly 4 athletes in a relay for our first, second, and third relays
# accounting for the opening leg not being a flying start in the non-MR relays
for j in relaynoMR:
    SwimMeetOpt += pl.lpSum(xFRvar[i][j] for i in athlete) == relaySize-1, "Exactly 3 legs in 1st relay %s"%j
    SwimMeetOpt += pl.lpSum(yFRvar[i][j] for i in athlete) == relaySize-1, "Exactly 3 legs in 2nd relay %s"%j
    SwimMeetOpt += pl.lpSum(zFRvar[i][j] for i in athlete) == relaySize-1, "Exactly 3 legs in 3rd relay %s"%j
    SwimMeetOpt += pl.lpSum(xFRvarlead[i][j] for i in athlete) == 1, "Exactly 1 to start 1st relay %s"%j
    SwimMeetOpt += pl.lpSum(yFRvarlead[i][j] for i in athlete) == 1, "Exactly 1 to start 2nd relay %s"%j
    SwimMeetOpt += pl.lpSum(zFRvarlead[i][j] for i in athlete) == 1, "Exactly 1 to start 3rd relay %s"%j

# Exactly 4 athletes in the first, second, and third best medley relay
SwimMeetOpt += pl.lpSum(xMRvar[i][j] for i in athlete for j in stroke) == relaySize, "Exactly 4 in 1st MR"
SwimMeetOpt += pl.lpSum(yMRvar[i][j] for i in athlete for j in stroke) == relaySize, "Exactly 4 in 2nd MR"
SwimMeetOpt += pl.lpSum(zMRvar[i][j] for i in athlete for j in stroke) == relaySize, "Exactly 4 in 3rd MR"
```

```
# Athletes in at most Maxevent
for i in athlete:
    SwimMeetOpt += pl.lpSum(xvar[i][j] + yvar[i][j] + zvar[i][j] for j in indiv)  + pl.lpSum(xFRvar[i][j] + yFRvar[i][j] + zFRvar[i][j] + xFRvarlead[i]



##########################################################################################
# START: Added for SMI Changes
# For the SMI athlete restrict from assigning them the restricted events and build a lineup
#

print("Computing SMI for athlete ", SMI_athlete, " and event ", SMI_event)

# If user is blocking individual event for swimmer
for j in indiv:
    if ('All' in SMI_event) or (j in SMI_event):
        SwimMeetOpt += xvar[SMI_athlete][j]==0
        SwimMeetOpt += yvar[SMI_athlete][j]==0
        SwimMeetOpt += zvar[SMI_athlete][j]==0

# If user is blocking 200 Free Relay (F50) relay for swimmer
if ('All' in SMI_event) or ('F50' in SMI_event):
    for j in relaynoMR:
        SwimMeetOpt += xFRvar[SMI_athlete][j]==0
        SwimMeetOpt += yFRvar[SMI_athlete][j]==0
        SwimMeetOpt += zFRvar[SMI_athlete][j]==0
        SwimMeetOpt += xFRvarlead[SMI_athlete][j]==0
        SwimMeetOpt += yFRvarlead[SMI_athlete][j]==0
        SwimMeetOpt += zFRvarlead[SMI_athlete][j]==0

# if user is blocking 200 Med Relay (M50) for swimmer
if ('All' in SMI_event) or ('M50' in SMI_event):
    for j in stroke:
        SwimMeetOpt += xMRvar[SMI_athlete][j]==0
        SwimMeetOpt += yMRvar[SMI_athlete][j]==0
        SwimMeetOpt += zMRvar[SMI_athlete][j]==0

# END: Added for SMI Changes
###############################################################################################


# Athletes in at most Maxrelayevent
for i in athlete:
    SwimMeetOpt += pl.lpSum(xFRvar[i][j] + yFRvar[i][j] + zFRvar[i][j] + xFRvarlead[i][j] + yFRvarlead[i][j] + zFRvarlead[i][j] for j in relaynoMR)+ pl
    # Athletes in at most Maxindivevent
    SwimMeetOpt += pl.lpSum(xvar[i][j] + yvar[i][j] + zvar[i][j] for j in indiv) <= Maxindevent,"Max Indiv events for athlete %s"%i

    # Back to back event constraints
    #HARD CODED WITH EVENT NAMES AND NEEDS TO BE CHECKED
    '''
    SwimMeetOpt += xvar[i]["100F"] + yvar[i]["100F"] + zvar[i]["100F"] + xvar[i]["500F"] + yvar[i]["500F"] + zvar[i]["500F"]<= 1,"No back to back 100F/
    SwimMeetOpt += xvar[i]["200F"] + yvar[i]["200F"] + zvar[i]["200F"] + xvar[i]["200IM"] + yvar[i]["200IM"] + zvar[i]["200IM"]<= 1,"No back to back 20
    SwimMeetOpt += xvar[i]["100BS"] + yvar[i]["100BS"] + zvar[i]["100BS"] + xvar[i]["100BR"] + yvar[i]["100BR"] + zvar[i]["100BR"]<= 1,"No back to back
    '''

    # Athletes can only be one of the 1st, 2nd, or 3rd ranked atheletes assigned to an event j
```

```
        for j in indiv:
            SwimMeetOpt += xvar[i][j] + yvar[i][j] + zvar[i][j] <= 1,"athlete %s can only be one of the 1st, 2nd, or 3rd ranked athletes assigned to an eve

    #Athletes can only be 1st, 2nd, or 3rd ranked relay team for each relay j
    for i in athlete:
        for j in relaynoMR:
            SwimMeetOpt += xFRvar[i][j] + yFRvar[i][j] + zFRvar[i][j] + xFRvarlead[i][j] + yFRvarlead[i][j] + zFRvarlead[i][j] <= 1,"athlete %s can only be

        # Each athlete can only perform one stroke in medley relay
        SwimMeetOpt += pl.lpSum(xMRvar[i][j]+yMRvar[i][j]+zMRvar[i][j] for j in stroke) <= 1, "Athlete %s can only perform one stroke in medley relay"%i


    #Each stroke on each relay team can only have one athlete assigned
    for j in stroke:
        SwimMeetOpt += pl.lpSum(xMRvar[i][j]for i in athlete) <= 1, "Stroke %s on 1st MR can only have one athlete"%j
        SwimMeetOpt += pl.lpSum(yMRvar[i][j]for i in athlete) <= 1, "Stroke %s on 2nd MR can only have one athlete"%j
        SwimMeetOpt += pl.lpSum(zMRvar[i][j]for i in athlete) <= 1, "Stroke %s on 3rd MR can only have one athlete"%j

    #realized rank of athletes from assignments
    #IF NO RUNNER, NEED TO ASSIGN A time larger than the third runner, smaller than the BigM for rank
    for j in indiv:
        SwimMeetOpt += rvar[1][j] == pl.lpSum(playperf[i][j]*xvar[i][j] for i in athlete) + 0.5*Big_M[j] + 1.0 - pl.lpSum(xvar[i][j]*(0.5*Big_M[j] + 1.0) f
        SwimMeetOpt += rvar[2][j] == pl.lpSum(playperf[i][j]*yvar[i][j] for i in athlete) + 0.5*Big_M[j] + 2.0 - pl.lpSum(yvar[i][j]*(0.5*Big_M[j] + 2.0) f
        SwimMeetOpt += rvar[3][j] == pl.lpSum(playperf[i][j]*zvar[i][j] for i in athlete) + 0.5*Big_M[j] + 3.0 - pl.lpSum(zvar[i][j]*(0.5*Big_M[j] + 3.0) f

     # The problem data is written to an .lp file
    #SwimMeetOpt.writeLP("SwimMeetOpt.lp")

    #WARNING: Sloppy hard code fix for legacy data structure
    playperfLeg = dict()
    playperfLead = dict()
    for i in athlete:
        # declare dicts
        playperfLeg[i] = dict()
        playperfLead[i] = dict()
        for j in relaynoMR:
            playperfLeg[i][j] = playperf[i]['F1F50A']
            playperfLead[i][j] = playperf[i]['FLF50A']

    for j in relaynoMR:
        SwimMeetOpt += rvar[1][j] == pl.lpSum(playperfLeg[i][j]*xFRvar[i][j] + playperfLead[i][j]*xFRvarlead[i][j] for i in athlete) + relaySize*0.5*Big_M[
        SwimMeetOpt += rvar[2][j] == pl.lpSum(playperfLeg[i][j]*yFRvar[i][j] + playperfLead[i][j]*yFRvarlead[i][j] for i in athlete) + relaySize*0.5*Big_M[
        SwimMeetOpt += rvar[3][j] == pl.lpSum(playperfLeg[i][j]*zFRvar[i][j] + playperfLead[i][j]*zFRvarlead[i][j] for i in athlete) + relaySize*0.5*Big_M[

    SwimMeetOpt += rvar[1]["M50"] == pl.lpSum(playperf[i][j]*xMRvar[i][j] for i in athlete for j in stroke) + relaySize*0.5*Big_M["M50"] + relaySize*1.0 -
    SwimMeetOpt += rvar[2]["M50"] == pl.lpSum(playperf[i][j]*yMRvar[i][j] for i in athlete for j in stroke) + relaySize*0.5*Big_M["M50"] + relaySize*2.0 -
    SwimMeetOpt += rvar[3]["M50"] == pl.lpSum(playperf[i][j]*zMRvar[i][j] for i in athlete for j in stroke) + relaySize*0.5*Big_M["M50"] + relaySize*3.0 -

    #force consistency in rank order
    for k in homerank:
        for j in tot_scored_events:
            if k < Tophomerank:
                SwimMeetOpt += rvar[k][j] <= rvar[k+1][j]

    #runner/team of rank k can be place in at most one place (1st, 2nd, or 3rd) vs opp 1
    for j in indiv:
```

```
    for k in homerank:
        for s in scenario:
            SwimMeetOpt += pl.lpSum(wvar[j][k][l][s] for l in place if l >= k) <= 1
for j in relay:
    for k in homerank:
        for s in scenario:
            SwimMeetOpt += pl.lpSum(wvar[j][k][l][s] for l in place if l >= k) <= 1

#Did your first runner 1st runner 1st, 2nd in 2nd or 3rd in third vs opp
for j in indiv:
    for k in homerank:
        for l in place:
            for s in scenario:
                if k==l:
                    #print("ath: ",j,"homerank: ",k,"place: ",l, "scen: ",s)
                    SwimMeetOpt += rvar[k][j] <= opptime[s][1][j]*wvar[j][k][l][s] + Big_M[j] - Big_M[j]*wvar[j][k][l][s]
                if l>k and l<(TopopprankIndiv + k):
                    #print("ath: ",j,"homerank: ",k,"place: ",l, "scen: ",s, "l-k+1: ", l-k+1)
                    SwimMeetOpt += rvar[k][j] <= opptime[s][l-k+1][j]*wvar[j][k][l][s] + Big_M[j] - Big_M[j]*wvar[j][k][l][s]
                if l>k  and l<=(TopopprankIndiv + k):
                    #print("ath: ",j,"homerank: ",k,"place: ",l, "scen: ",s, "l-k: ", l-k)
                    SwimMeetOpt += rvar[k][j] >= opptime[s][l-k][j]*wvar[j][k][l][s]

#Did your first relay 1st runner 1st, 2nd in 2nd or 3rd in third vs opp
for j in relay:
    for k in homerank:
        for l in place:
            for s in scenario:
                if k==l:
                    SwimMeetOpt += rvar[k][j] <= opptime[s][1][j]*wvar[j][k][l][s] + 5*Big_M[j]- 5*Big_M[j]*wvar[j][k][l][s]
                if l>k and l< (TopopprankRelay + k):
                    SwimMeetOpt += rvar[k][j] <= opptime[s][l-k+1][j]*wvar[j][k][l][s] + 5*Big_M[j]- 5*Big_M[j]*wvar[j][k][l][s]
                if l>k  and l<=(TopopprankRelay + k):
                    SwimMeetOpt += rvar[k][j] >= opptime[s][l-k][j]*wvar[j][k][l][s]

#Report the total setup time
setupStop = time.time()
print("Total Setup Time = ", int(setupStop - setupStart), " secs")

# The problem data is written to an .lp file
SwimMeetOpt.writeLP("SwimMeetOpt.lp")

SwimMeetOpt.setSolver(solver)

#Solve the WHOLE problem with selected Solver and report it to Excel
print("Solve the baseline problem:")
solveStart = time.time()
SwimMeetOpt.solve()
solveStop = time.time()
print(" Total Solve Time = ", int((solveStop - solveStart)/60.0), " mins")

#The status of the solution is printed to the screen
print(" Status:", pl.LpStatus[SwimMeetOpt.status])
print(" Objective:", pl.value(SwimMeetOpt.objective), " points")

#Return the objective function value for the best feasible soln found
```

```
BestObjective = pl.lpSum(scenprob[s]*scenscorevar[s].varValue for s in scenario)
print(" Best Found Solution Objective= ", BestObjective)

OptObj = pl.value(SwimMeetOpt.objective)
scenscore = dict()
for s in scenario:
    scenscore[s] = scenscorevar[s].varValue
    print(" Score under Scenario ",s, "is ", int(scenscorevar[s].varValue))


# Each of the variables is printed with it's resolved optimum value

optLineup = {}
for i in athlete:
    optLineup[i] = {}
    for j in indiv:
        optLineup[i][j] = xvar[i][j].varValue + yvar[i][j].varValue + zvar[i][j].varValue
    # TO DO!! Add code for other relays
    optLineup[i]['FLF50A'] = xFRvarlead[i]['F50'].varValue
    optLineup[i]['F1F50A'] = xFRvar[i]['F50'].varValue
    optLineup[i]['FLF50B'] = yFRvarlead[i]['F50'].varValue
    optLineup[i]['F1F50B'] = yFRvar[i]['F50'].varValue
    optLineup[i]['FLF50C'] = zFRvarlead[i]['F50'].varValue
    optLineup[i]['F1F50C'] = zFRvar[i]['F50'].varValue

    # No need for D teams
    optLineup[i]['FLF50D'] = 0
    optLineup[i]['F1F50D'] = 0

    for j in stroke:
        leg = j[:-1]
        optLineup[i][leg+'A'] = xMRvar[i][j].varValue
        optLineup[i][leg+'B'] = yMRvar[i][j].varValue
        optLineup[i][leg+'C'] = zMRvar[i][j].varValue
        #print("ath ", i, " stroke ", leg+'C', " is ", zMRvar[i][j].varValue)
        # No need for D teams
        optLineup[i][leg+'D'] = 0

##########################
# START: Save the finish place and time

HomeAthPredTime = {}
HomeAthFinPlace = {}
for j in tot_scored_events:
    HomeAthPredTime[j] = {}
    HomeAthFinPlace[j] = {}
    for k in homerank:
        # mins = int(rvar[k][j].varValue/60)
        # secs = rvar[k][j].varValue - mins*60
        # HomeAthPredTime[j][k] = str(mins)+":"+str(secs)
        HomeAthPredTime[j][k] = rvar[k][j].varValue
        for p in place:
            if wvar[j][k][p][1].varValue == 1:
                HomeAthFinPlace[j][k] = p

# END: Save the finish place and time
```

```
    ##########################

    #Return the lineup found in form of a 2-D dictionary of assignment for each athlete
    #NEED this to match the events and A/B/C team of relays.
    optlineup_df = pd.DataFrame.from_dict(optLineup)
    optLUtime_df = pd.DataFrame.from_dict(HomeAthPredTime)
    optLUplace_df = pd.DataFrame.from_dict(HomeAthFinPlace)

    # Return the transpose to get swimmers as index
    return optlineup_df.T, optLUtime_df, optLUplace_df
```

Check for Team A LU 1 vs. Team B LU 0 (expected score of Team A 146) and for athlete 233487

[167013, 214963, 221480, 228451, 233487, 233650, 235482, 255871, 256775, 260001, 265562, 270043, 329465, 330237, 330324, 342607, 342611, 344005, 347298, 356813, 382148, 395502, 402879, 403012, 409578, 586800]

In [ ]:

```
# opponents times needs to be in lineup (or scenario), opponent rank (1,2,3,4), then the name of the scored event
TeamB_lineupNums = 1
opptime_TeamB_dict = dict()
for i in range(TeamB_lineupNums):
    # Doing this for LU 1 for Team B
    opptime_TeamB_dict[i+1] = create_opptime_dict(TeamB_Perf_wM_df, TeamB_Lineup_df[0], BigM)

print(opptime_TeamB_dict[1][2])
```

```
{'M50': 110.65899999999999, 'F50': 177.439, 'F11650Y': 1046.029, 'F1200Y': 109.719, 'F2100Y': 57.549, 'F3100Y': 65.81899999999999, 'F4200Y': 122.839, 'F150
Y': 23.198999999999998, 'F1100Y': 50.149, 'F2200Y': 124.169, 'F3200Y': 142.47899999999998, 'F1500Y': 300.35900000000004, 'F4100Y': 56.159, 'F5200Y': 126.69
9}
```

In [ ]:

```
# Find MeetOpt response lineup to the base
TeamA_Lineup_SMI,_,_ = MeetOptwSMI(TeamA_swimmers, oppB_lineup_nums, oppB_scenario_prob, individual_scored_events, \
    relay_scored_events, relay_noMR, MR_legs,relay_pastperf_events,Lineup_Events,TeamA_Perf_dict,opptime_TeamB_dict,228451,'All', BigM)

# Reorder the columns to the meet event order
TeamA_Lineup_SMI = TeamA_Lineup_SMI[EventOrder]
```

In [ ]:

```
# Which lineups to score in a competition?
TeamB_LU = 0

TeamA_Lineup_SMI = TeamA_Lineup_SMI[TeamA_Lineup_SMI.columns].round().astype('int8')

score_A,score_B,eventScore_df_6 = calculate_pred_score(TeamA_Perf_wM_df, TeamA_Lineup_SMI, \
    TeamB_Perf_wM_df, TeamB_Lineup_df[TeamB_LU], scoring_method="Six Lane")

print("Projected scores: \nTeam A: ",score_A,"\nTeam B: ",score_B, "\nDifference: ", score_A-score_B)
```

```
Projected scores:
Team A:  142.0
Team B:  120.0
Difference:  22.0
```

So, swimmer '228451' has a SMI of 4 points since 146 was the score for Team A using LU 1 vs Team B LU 0 when the swimmer was included.

Let's check the rest of the team Team A LU 1 vs Team B LU 0. All Team A swimmers are replaceable.

In [ ]:

```
# Create a dataframe for the swimmer SMI scores for just Team A ('184')
TeamA_Swimmer_SMI = Swimmer_Names_df[Swimmer_Names_df['team_id'] == 184].copy()
TeamA_Swimmer_SMI['All'] = np.nan
```

In [ ]:

```
Base_Score = 146

for swimmer_id in TeamA_swimmers:
    TeamA_Lineup_SMI,_,_ = MeetOptwSMI(TeamA_swimmers, oppB_lineup_nums, oppB_scenario_prob, individual_scored_events, \
    relay_scored_events, relay_noMR, MR_legs,relay_pastperf_events,Lineup_Events,TeamA_Perf_dict,opptime_TeamB_dict,swimmer_id,'All', BigM)

    TeamA_Lineup_SMI = TeamA_Lineup_SMI[TeamA_Lineup_SMI.columns].round().astype('int8')

    score_A,score_B,eventScore_df = calculate_pred_score(TeamA_Perf_wM_df, TeamA_Lineup_SMI, \
    TeamB_Perf_wM_df, TeamB_Lineup_df[0], scoring_method="Six Lane")

    TeamA_Swimmer_SMI.at[swimmer_id,'All'] = Base_Score - score_A
```

In [ ]:

```
# Check the scores
TeamA_Swimmer_SMI = TeamA_Swimmer_SMI.dropna().sort_values(by='All', ascending=False).set_index('name').drop(columns=['gender','team_id'])
```

In [ ]:

```
# Displaying dataframe as an heatmap
fig, axs = plt.subplots(1, 1, figsize=(3, 10), constrained_layout=True)

g = sns.heatmap(TeamA_Swimmer_SMI, linewidths = 0.3, annot = True,
            annot_kws={"size": 12},cbar= False, square= False, xticklabels= False, cmap= 'Blues')


g.set(ylabel=None)
g.set_xlabel('SMI')
axs.xaxis.set_label_position('top')
axs.xaxis.tick_top()
g.tick_params(left=False, top=False) ## other options are right and top


plt.show()
```

	SMI
Maggie Wyngowski	11
Lindsay Smalec	7
Maddie Hartigan	6
Abigail Rosenberg	6
Emma Hadley	5
Julie Byrne	4
Mary Weinstein	4
Abigail Merriman	4
Meagan Hathaway	2
Alexis Lexi Faria	2
Stephanie Boyd	2
Meghan Taner	0
Katherine O'Shea	0
Lindsey Bloom	0
Caroline Mayk	0
Michaela Peil	0
Kelly Cattano	0
Emily Gorham	0
Isabella Smith	0
Megan Koczur	0
Rachel Hazard	0
Amanda Lauer	0
Brooke Collins	0
Maura Mcmanus	0
Megan Barpoulis	0
Courtney Wolfgang	0

Can also do for all swimmer and event pairs and store in a dataframe

In [ ]:

```
# Create a dataframe for the swimmer SMI scores for just Team A ('184')
TeamA_SMI = Swimmer_Names_df[Swimmer_Names_df['team_id'] == 184].copy()

TeamA_SMI = TeamA_SMI.drop(columns=['gender','team_id'])

TeamA_SMI.head()
```

Out[ ]:

swimmer_id	name
167013	Katherine O'Shea
214963	Mary Weinstein
221480	Megan Barpoulis
228451	Julie Byrne
233487	Lindsay Smalec

In [ ]:

```
# Create an empty column for swimmer SMI score
TeamA_SMI['All'] = np.nan

# Create columns for each event for swimmer-event SMI
tot_scored_events = individual_scored_events + relay_scored_events
for ev in tot_scored_events:
    TeamA_SMI[ev] = np.nan

TeamA_SMI = TeamA_SMI[['name','All'] + EventScoreOrder]
TeamA_SMI.head()
```

Out[ ]:

swimmer_id	name	All	M50	F11650Y	F1200Y	F2100Y	F3100Y	F4200Y	F150Y	F1100Y	F2200Y	F3200Y	F1500Y	F4100Y	F5200Y	F50
167013	Katherine O'Shea	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
214963	Mary Weinstein	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
221480	Megan Barpoulis	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
228451	Julie Byrne	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
233487	Lindsay Smalec	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN

In [ ]:

```
# List of events to eliminate (including 'All'). It has memory issues if you try to do the full list of events, but can do a few at a time
# Write to file
# Event codes: = ['All', 'M50','F11650Y','F1200Y','F2100Y','F3100Y','F4200Y','F150Y','F1100Y','F2200Y','F3200Y','F1500Y','F4100Y','F5200Y','F50']
ev = ['F4100Y','F5200Y','F50']

# This is for Team A LU 1 vs. Team B LU 0
# Check the SMI for the swimmer and event (ev) pair
for event in ev:
    for swimmer_id in TeamA_swimmers:

        TeamA_Lineup_SMI,_,_ = MeetOptwSMI(TeamA_swimmers, oppB_lineup_nums, oppB_scenario_prob, individual_scored_events, \
            relay_scored_events, relay_noMR, MR_legs,relay_pastperf_events,Lineup_Events,TeamA_Perf_dict,opptime_TeamB_dict, swimmer_id, [event], BigM)

        TeamA_Lineup_SMI = TeamA_Lineup_SMI[TeamA_Lineup_SMI.columns].round().astype('int8')

        score_A,_,_ = calculate_pred_score(TeamA_Perf_wM_df, TeamA_Lineup_SMI, \
            TeamB_Perf_wM_df, TeamB_Lineup_df[0], scoring_method="Six Lane")
```

```
        TeamA_SMI.at[swimmer_id,event] = Base_Score - score_A
```

In [ ]:

```
TeamA_SMI
```

In [ ]:

```
# Write table to CSV
TeamA_SMI.to_csv('Bucknell_SMI.csv')
```

In [ ]:

```
# Order swimmers by their 'All' SMI and set the index to the names
TeamA_SMI = TeamA_SMI.dropna().sort_values(by='All', ascending=False).set_index('name')
```

In [ ]:

```
# Order the columns by
TeamA_SMI = TeamA_SMI[['All'] + EventScoreOrder]

# Rename the events
TeamA_SMI = TeamA_SMI.rename(columns=EventScoreLabelConvertDict)

TeamA_SMI
```

In [ ]:

```
# Make a pretty SMI Table by displaying dataframe as an heatmap
fig, axs = plt.subplots(1, 1, figsize=(13, 10), constrained_layout=True)

g = sns.heatmap(TeamA_SMI, linewidths = 0.3, annot = True,
            annot_kws={"size": 12},cbar= False, square= False, xticklabels= True, cmap= 'Blues', linecolor= '.75')


#clean up the charts
fig.suptitle('Swimmer\'s Meet Impact (SMI) Score')

g.set(ylabel=None)
axs.xaxis.set_label_position('top')
axs.xaxis.tick_top()
g.tick_params(left=False, top=False) ## other options are right and top

plt.xticks(rotation=90)

plt.show()
```

Swimmer's Meet Impact (SMI) Score

	All	200Y Medley Relay	1650Y Free	200Y Free	100Y Back	100Y Breast	200Y Fly	50Y Free	100Y Free	200Y Back	200Y Breast	500Y Free	100Y Fly	200Y IM	200Y Free Relay
Maggie Wyngowski	11	0	0	0	0	2	0	0	0	0	8	0	0	1	0
Lindsay Smalec	7	0	0	0	0	0	0	0	0	0	0	0	7	0	0
Maddie Hartigan	6	0	0	1	0	0	0	0	0	0	0	2	0	0	0
Abigail Rosenberg	6	0	0	2	0	0	0	2	2	0	0	0	0	0	0
Emma Hadley	5	0	0	0	1	0	0	0	0	2	0	0	2	0	0
Julie Byrne	4	0	0	0	1	0	0	0	0	2	0	0	0	1	0
Mary Weinstein	4	0	0	0	0	3	0	0	0	0	1	0	0	0	0
Abigail Merriman	4	0	1	0	0	0	0	0	0	0	0	3	0	0	0
Meagan Hathaway	2	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Alexis Lexi Faria	2	0	0	0	0	0	0	0	0	0	0	0	2	0	0
Stephanie Boyd	2	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Meghan Taner	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Katherine O'Shea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lindsey Bloom	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Caroline Mayk	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Michaela Peil	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kelly Cattano	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Emily Gorham	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Isabella Smith	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Megan Koczur	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rachel Hazard	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amanda Lauer	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Brooke Collins	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Maura Mcmanus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Megan Barpoulis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Courtney Wolfgang	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Because of ties in the relays. We can subtract 0.001 (due to the precision of the input data, this won't have a real affect except to avoid ties) from the opptime values to force MeetOpt to look for a "non-tie" lineup. This shouldn't be an issue as long an equal point solution exists. In this meet with these teams, that is true.

In [ ]:

```
#####
# Debugging Code
# Check LU 1 vs the LU missing this swimmer
TeamA_3colors = [TeamA_orange, (1,1,1), TeamA_blue ]
ChartLUdiff('TeamA',TeamA_3colors, TeamA_Lineup_df[1], TeamA_Lineup_SMI, 9, 7)
```

In [ ]:
```
#####
# Debugging Code

print((TeamB_Lineup_df[0]*TeamB_Perf_wM_df)[['FLF50A', 'F1F50A']].sum().sum(), "  ",\
    (TeamB_Lineup_df[0]*TeamB_Perf_wM_df)[['FLF50B', 'F1F50B']].sum().sum(), "  ", \
    (TeamB_Lineup_df[0]*TeamB_Perf_wM_df)[['FLF50C', 'F1F50C']].sum().sum())
```

```
92.0    177.44    354.75
```

In [ ]:
```
#####
# Debugging Code

print((TeamA_Lineup_df[1]*TeamA_Perf_wM_df)[['FLF50A', 'F1F50A']].sum().sum(), "  ",\
    (TeamA_Lineup_df[1]*TeamA_Perf_wM_df)[['FLF50B', 'F1F50B']].sum().sum(), "  ", \
    (TeamA_Lineup_df[1]*TeamA_Perf_wM_df)[['FLF50C', 'F1F50C']].sum().sum())
```

```
95.31    96.30000000000001    443.28
```

In [ ]:
```
#####
# Debugging Code

print((TeamA_Lineup_SMI*TeamA_Perf_wM_df)[['FLF50A', 'F1F50A']].sum().sum(), "  ",\
    (TeamA_Lineup_SMI*TeamA_Perf_wM_df)[['FLF50B', 'F1F50B']].sum().sum(), "  ", \
    (TeamA_Lineup_SMI*TeamA_Perf_wM_df)[['FLF50C', 'F1F50C']].sum().sum())
```

```
177.31    177.44    443.28
```

In [ ]:
```
#####
# Debugging Code
(TeamA_Lineup_SMI*TeamA_Perf_wM_df)[['FLF50B', 'F1F50B']].sum()
```

Out[ ]:
```
FLF50B    105.96
F1F50B     71.48
dtype: float64
```

In [ ]:
```
#####
# Debugging Code
(TeamB_Lineup_df[0]*TeamB_Perf_wM_df)[['FLF50B', 'F1F50B']].sum()
```

Out[ ]:
```
FLF50B    105.96
F1F50B     71.48
dtype: float64
```

"Ghost" Swimmers should be added if the team cannot create a feasible lineup with 3 in each indiv event and 12 in relay events.