In [81]:
```python
import numpy as np
import pandas as pd
from matplotlib import pyplot as plt
import seaborn as sns
from sklearn.model_selection import train_test_split
from sklearn.model_selection import GridSearchCV,RandomizedSearchCV
from sklearn.model_selection import StratifiedKFold
from sklearn.metrics import accuracy_score,roc_auc_score,f1_score,precision_score,reca
from sklearn.model_selection import RepeatedKFold
from sklearn.model_selection import cross_val_score

from sklearn.linear_model import LogisticRegression
from sklearn.ensemble import RandomForestClassifier
from sklearn.svm import SVC
from sklearn.neighbors import KNeighborsClassifier
import xgboost
from imblearn.over_sampling import SMOTE

import tensorflow as tf
import keras
from keras.wrappers.scikit_learn import KerasClassifier
from keras.models import Sequential
from keras.layers import Dense,Dropout
from imblearn.over_sampling import SMOTE
from keras.regularizers import l1_l2

import warnings
warnings.filterwarnings('ignore')
```

In [51]:
```python
feature_data = pd.read_csv('https://raw.githubusercontent.com/rsdevanathan/Customer_Su
```

In [52]:
```python
feature_data.head()
```

Out[52]:

	age	duration	campaign	previous	job_admin.	job_blue-collar	job_entrepreneur	job_housemaid
0	0.889105	-0.115910	0.655440	-0.361371	0.0	1.0	0.0	0.0
1	-0.289767	-0.222792	-0.215515	1.744512	0.0	0.0	1.0	0.0
2	3.049388	3.821615	-0.650993	-0.361371	0.0	0.0	0.0	0.0
3	-0.388006	-0.573364	-0.215515	-0.361371	1.0	0.0	0.0	0.0
4	1.871499	0.486903	-0.215515	-0.361371	0.0	0.0	0.0	0.0

5 rows × 58 columns

Train Test Split - 80:20

In [53]:
```python
X = feature_data.drop(columns = 'y')
y = feature_data[['y']]
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size = 0.2, random_stat
cw = {0:1,1:np.count_nonzero(y_train==0)/np.count_nonzero(y_train==1)}
```

Metric Utility

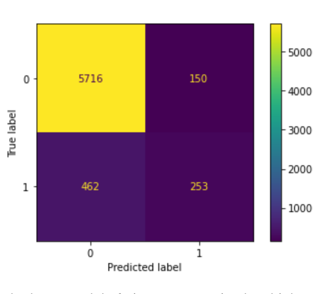
In [54]:
```python
def metric_utility(model,X_train, y_train,X_test,y_test):
  y_pred = model.predict(X_test)
  kfold = StratifiedKFold(n_splits=3, shuffle=True)
  cv_auc = cross_val_score(model, X_train, y_train, scoring='roc_auc',cv=kfold)
  metric_df =  pd.DataFrame({
                              'Train_AUC' :np.mean(cv_auc),
                              'Test_AUC' :[roc_auc_score(y_test,y_pred)],
                              'Test_Accuracy' :[accuracy_score(y_test,y_pred)],
                              'Test_F1_score' :[f1_score(y_test,y_pred)],
                              'Test_Precision' :[precision_score(y_test,y_pred)],
                              'Test_Recall' :[recall_score(y_test,y_pred)]})
  #print(metric_df)
  cm = confusion_matrix(y_test, y_pred, labels=[0., 1.])
  disp = ConfusionMatrixDisplay(cm)
  disp.plot();
  return metric_df
```

Logistic regression - Base Model

In [55]:
```python
ml_lr_base = LogisticRegression(max_iter=1000)
ml_lr_base.fit(X_train,y_train)
y_pred = ml_lr_base.predict(X_test)
metric_utility(ml_lr_base,X_train, y_train,X_test,y_test)
```

Out[55]:

	Train_AUC	Test_AUC	Test_Accuracy	Test_F1_score	Test_Precision	Test_Recall
0	0.913407	0.664138	0.907005	0.452594	0.627792	0.353846



The base model of Linear Regression has high Accuracy but all other metrics are poor. Also the train AUC is much higher than the Test AUC. It is due to the imbalance in the target variable as visible in the confusion matrix. The model is performing poor in identifying subscriptions. The false negative is too high causing poor recall score.

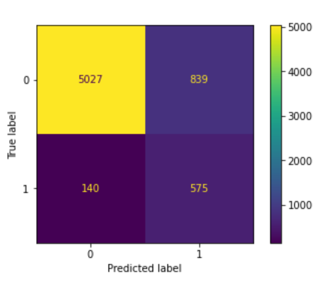
Below, I have tried oversampling the data using SMOTE package to handle the imbalanced target variable. The Logistic Regression is performing much better after the resampling.

In [56]:
```python
smote_sampler = SMOTE(random_state=14)
columns = X_train.columns
arr_X, arr_y = smote_sampler.fit_resample(X_train, y_train)
sampled_X = pd.DataFrame(data=arr_X,columns=X_train.columns )
sampled_y = pd.DataFrame(data=arr_y,columns=['y'])
```

In [57]:
```python
ml_lr = LogisticRegression(max_iter=1000)
ml_lr.fit(sampled_X,sampled_y)
metric_utility(ml_lr,X_train, y_train,X_test,y_test)
```

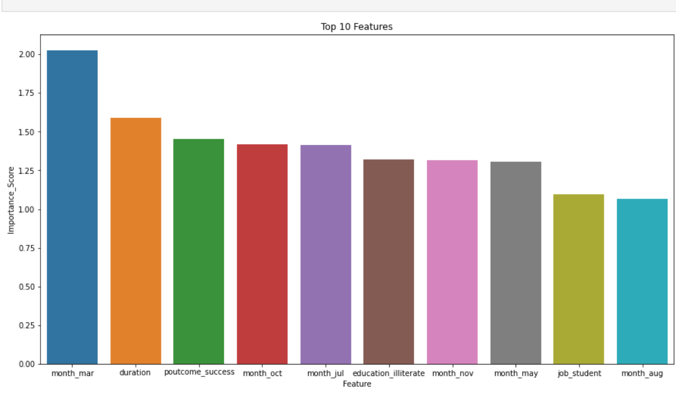
Out[57]:

	Train_AUC	Test_AUC	Test_Accuracy	Test_F1_score	Test_Precision	Test_Recall
0	0.913613	0.830584	0.851238	0.54016	0.406648	0.804196



Linear Regression Feature Importance

In [86]:
```python
importance_df = pd.DataFrame({'Feature':X_train.columns,'Importance_Score':np.abs(ml_l
plot_df = importance_df.nlargest(10, ['Importance_Score'])
plt.figure(figsize=(15,8))
ax = sns.barplot(x="Feature", y="Importance_Score", data=plot_df).set(title='Top 10 Fe
plt.show()
```



KNN Classifier - with Hyper Parameter Tuning

In [58]:
```python
%%time
ml_knn_hp=KNeighborsClassifier()
param_grid = {
    'leaf_size': list(range(5,20)),
    'n_neighbors': list(range(5,20)),
    'p' : [1,2],
}
CV_knn = RandomizedSearchCV(estimator=ml_knn_hp, param_distributions=param_grid,scorin
CV_knn.fit(sampled_X, sampled_y)
```

```
Fitting 3 folds for each of 20 candidates, totalling 60 fits
CPU times: user 4.4 s, sys: 679 ms, total: 5.07 s
Wall time: 11min 41s
```

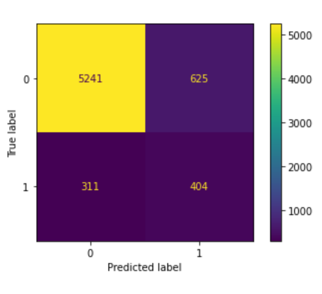
In [59]:
```python
CV_knn.best_params_
```

Out[59]: {'leaf_size': 7, 'n_neighbors': 7, 'p': 1}

In [60]:
```python
ml_knn=KNeighborsClassifier(leaf_size=7,n_neighbors=7,p=1)
ml_knn.fit(sampled_X, sampled_y)
metric_utility(ml_knn,X_train, y_train,X_test,y_test)
```

Out[60]:

	Train_AUC	Test_AUC	Test_Accuracy	Test_F1_score	Test_Precision	Test_Recall
0	0.830518	0.729244	0.857772	0.463303	0.392614	0.565035



SVC - with Hyperparameter tuning

In [64]:
```python
%%time
ml_svc_hp=SVC(gamma='auto')
param_grid = {'C': [1, 10, 100]}
CV_svc = RandomizedSearchCV(estimator=ml_svc_hp, param_distributions=param_grid,scorin
CV_svc.fit(sampled_X, sampled_y)
```

```
Fitting 3 folds for each of 9 candidates, totalling 27 fits
CPU times: user 3min 8s, sys: 1.66 s, total: 3min 10s
Wall time: 27min 20s
```

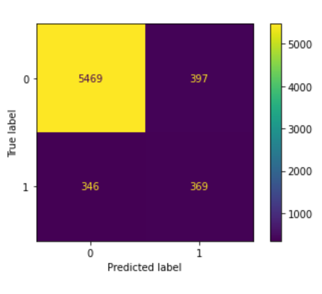
In [65]:
```python
CV_svc.best_params_
```

Out[65]: {'C': 10, 'gamma': 0.1, 'kernel': 'rbf'}

In [66]:
```python
ml_svc=SVC(gamma=0.1,C=10,kernel='rbf')
ml_svc.fit(sampled_X, sampled_y)
metric_utility(ml_svc,X_train, y_train,X_test,y_test)
```

Out[66]:

	Train_AUC	Test_AUC	Test_Accuracy	Test_F1_score	Test_Precision	Test_Recall
0	0.892375	0.724203	0.887099	0.498312	0.481723	0.516084



Random Forest Classifier - with Hyperparameter Tuning

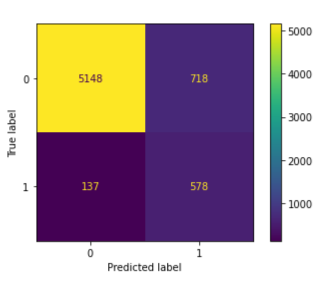
In [ ]:
```python
%%time

ml_rf_hp=RandomForestClassifier(class_weight = cw,random_state=14)
param_grid = {
    'n_estimators': [int(x) for x in np.linspace(start = 100, stop = 500, num = 5)],
    'max_features': ['auto', 'sqrt','log2'],
    'max_depth' : [10,20,50,100],
    'min_samples_leaf': [2,5,10],
}
CV_rf = RandomizedSearchCV(estimator=ml_rf_hp, param_distributions=param_grid,scoring=
CV_rf.fit(X_train, y_train)
```

In [ ]:
```python
CV_rf.best_params_
```

In [67]:
```python
ml_rf=RandomForestClassifier(random_state=14,class_weight = cw,max_depth=100,max_featu
ml_rf.fit(X_train, y_train)
metric_utility(ml_rf,X_train, y_train,X_test,y_test)
```

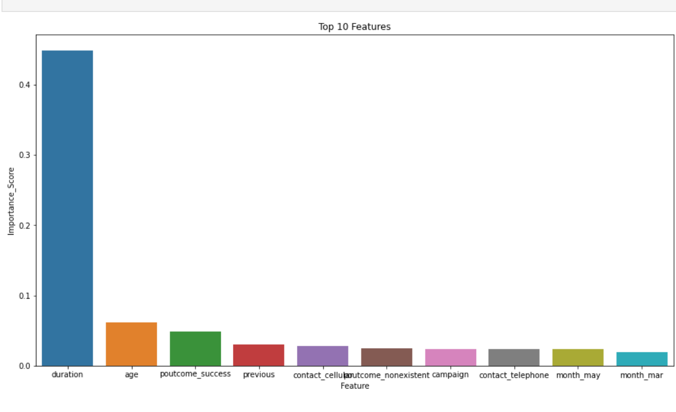
Out[67]:

	Train_AUC	Test_AUC	Test_Accuracy	Test_F1_score	Test_Precision	Test_Recall
0	0.926395	0.842996	0.870081	0.574838	0.445988	0.808392



Random Forest Feautre Importance

In [87]:
```python
importance_df = pd.DataFrame({'Feature':X_train.columns,'Importance_Score':np.abs(ml_r
plot_df = importance_df.nlargest(10, ['Importance_Score'])
plt.figure(figsize=(15,8))
ax = sns.barplot(x="Feature", y="Importance_Score", data=plot_df).set(title='Top 10 Fe
plt.show()
```



XGBoost - with Hyper Parameter Tuning

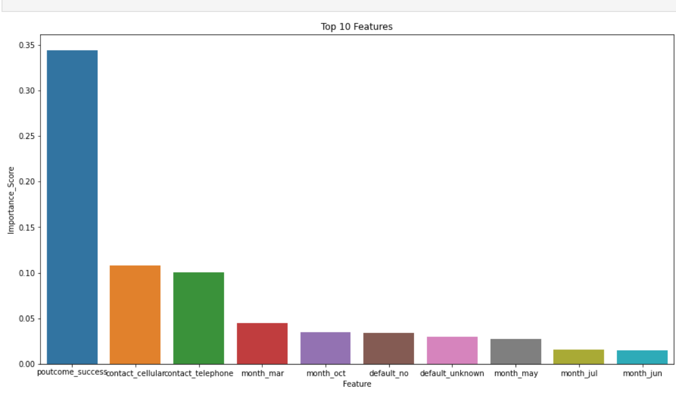
In [ ]:
```python
%%time
ml_xgb_hp = xgboost.XGBClassifier(objective='binary:logistic')

param_grid = [
  {
    'clf__n_estimators': [50, 100, 150, 200],
    'clf__learning_rate': [0.01, 0.1, 0.001],
    'clf__max_depth': range(50,200),
    'clf__colsample_bytree': [0.1,0.2,0.5],
    'clf__gamma': [0.1,0.2],
  }
]

CV_xgb = RandomizedSearchCV(estimator=ml_xgb_hp,param_distributions=param_grid,scorinc
CV_xgb.fit(sampled_X, sampled_y)
```

In [ ]:
```python
CV_xgb.best_params_
```

In [ ]:
```python
ml_xgb=xgboost.XGBClassifier(objective='binary:logistic',random_state=14,max_depth=30,
ml_xgb.fit(sampled_X, sampled_y)
metric_utility(ml_xgb,X_train, y_train,X_test,y_test)
```

XGBoost Feature importance

In [88]:
```python
importance_df = pd.DataFrame({'Feature':X_train.columns,'Importance_Score':np.abs(ml_x
plot_df = importance_df.nlargest(10, ['Importance_Score'])
plt.figure(figsize=(15,8))
ax = sns.barplot(x="Feature", y="Importance_Score", data=plot_df).set(title='Top 10 Fe
plt.show()
```

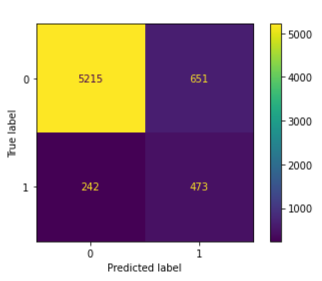


NN - Base

In [89]:
```python
def create_nn():
  model = Sequential()
  model.add(Dense(32, input_dim=57, activation='relu'))
  model.add(Dense(16, activation='relu'))
  model.add(Dense(1, activation='sigmoid'))
  model.compile(loss='binary_crossentropy', optimizer='adam', metrics=['binary_accurac
  return model
dl_cfr = KerasClassifier(build_fn=create_nn, epochs=100, batch_size=256, verbose=0)
dl_cfr.fit(sampled_X, sampled_y)
metric_utility(dl_cfr,X_train, y_train,X_test,y_test)
```

Out[89]:

	Train_AUC	Test_AUC	Test_Accuracy	Test_F1_score	Test_Precision	Test_Recall
0	0.912691	0.77528	0.864306	0.51441	0.420819	0.661538

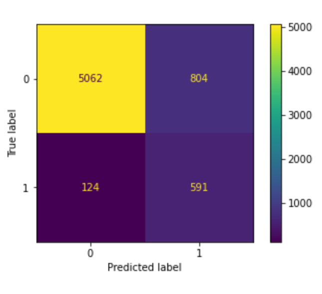


NN - Class Weights

In [90]:
```python
def create_nn():
  model = Sequential()
  model.add(Dense(32, input_dim=57, activation='relu'))
  model.add(Dense(16, activation='relu'))
  model.add(Dense(1, activation='sigmoid'))
  model.compile(loss='binary_crossentropy', optimizer='adam', metrics=['binary_accurac
  return model
dl_cfr_cw = KerasClassifier(build_fn=create_nn, epochs=100, batch_size=1028, verbose=(
dl_cfr_cw.fit(X_train, y_train,class_weight = cw)
metric_utility(dl_cfr_cw,X_train, y_train,X_test,y_test)
```

Out[90]:

	Train_AUC	Test_AUC	Test_Accuracy	Test_F1_score	Test_Precision	Test_Recall
0	0.922327	0.844756	0.858988	0.56019	0.423656	0.826573

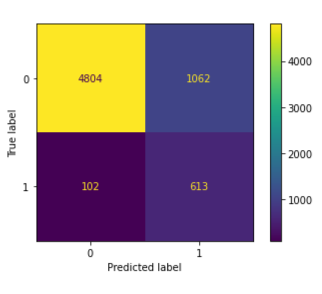


NN - Dropout and Regularization

In [91]:
```python
def create_nn():
  model = Sequential()
  model.add(Dense(32, input_dim=57,kernel_regularizer=l1_l2(l1=0.01, l2=0.01), bias_re
  model.add(Dropout(0.2))
  model.add(Dense(16,kernel_regularizer=l1_l2(l1=0.01, l2=0.01), bias_regularizer=l1_l
  model.add(Dropout(0.2))
  model.add(Dense(1, activation='sigmoid'))
  model.compile(loss='binary_crossentropy', optimizer='adam', metrics=['binary_accurac
  return model
dl_cfr_reg = KerasClassifier(build_fn=create_nn, epochs=100, batch_size=1028, verbose=
dl_cfr_reg.fit(X_train, y_train,class_weight = cw)
metric_utility(dl_cfr_reg,X_train, y_train,X_test,y_test)
```

Out[91]:

	Train_AUC	Test_AUC	Test_Accuracy	Test_F1_score	Test_Precision	Test_Recall
0	0.880053	0.83815	0.823127	0.512971	0.36597	0.857343



ML Experiments Code - Excluding Hyperparameter tuning and Plots

In [97]:
```python
import numpy as np
import pandas as pd
from sklearn.model_selection import train_test_split
from sklearn.model_selection import GridSearchCV,RandomizedSearchCV
from sklearn.model_selection import StratifiedKFold
from sklearn.metrics import accuracy_score,roc_auc_score,f1_score,precision_score,reca
from sklearn.model_selection import RepeatedKFold
from sklearn.model_selection import cross_val_score

from sklearn.linear_model import LogisticRegression
from sklearn.ensemble import RandomForestClassifier
from sklearn.svm import SVC
from sklearn.neighbors import KNeighborsClassifier
import xgboost
from imblearn.over_sampling import SMOTE

import warnings
warnings.filterwarnings('ignore')

def metric_utility(model,X_train, y_train,X_test,y_test):
  y_pred = model.predict(X_test)
  kfold = StratifiedKFold(n_splits=3, shuffle=True)
  cv_auc = cross_val_score(ml_lr_base, X_train, y_train, scoring='roc_auc',cv=kfold)
  metric_df =  pd.DataFrame({
                              'Train_AUC' :np.mean(cv_auc),
                              'Test_AUC' :[roc_auc_score(y_test,y_pred)],
                              'Test_Accuracy' :[accuracy_score(y_test,y_pred)],
                              'Test_F1_score' :[f1_score(y_test,y_pred)],
                              'Test_Precision' :[precision_score(y_test,y_pred)],
                              'Test_Recall' :[recall_score(y_test,y_pred)]})
  return metric_df

feature_data = pd.read_csv('https://raw.githubusercontent.com/rsdevanathan/Customer_Su
X = feature_data.drop(columns = 'y')
y = feature_data[['y']]
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size = 0.2, random_stat


## Model 1 - Logistic Regression - Base

ml_lr_base = LogisticRegression(max_iter=1000)
ml_lr_base.fit(X_train,y_train)
ml_lr_base_metrics = metric_utility(ml_lr_base,X_train, y_train,X_test,y_test)
ml_lr_base_metrics.insert(loc=0, column='Model Name', value='LR-BASE')

## Model 2 - Logistic Regression - Oversampled

ml_lr = LogisticRegression(max_iter=1000)
ml_lr.fit(sampled_X,sampled_y)
ml_lr_metrics = metric_utility(ml_lr,X_train, y_train,X_test,y_test)
ml_lr_metrics.insert(loc=0, column='Model Name', value='LR-OS')

## Model 3 - KNN

ml_knn=KNeighborsClassifier(leaf_size=14,n_neighbors=7,p=1)
ml_knn.fit(sampled_X, sampled_y)
ml_knn_metrics = metric_utility(ml_knn,X_train, y_train,X_test,y_test)
ml_knn_metrics.insert(loc=0, column='Model Name', value='KNN')

## Model 4 - SVC

ml_svc=SVC(gamma=0.1,C=10,kernel='rbf')
ml_svc.fit(sampled_X, sampled_y)
ml_svc_metrics = metric_utility(ml_svc,X_train, y_train,X_test,y_test)
ml_svc_metrics.insert(loc=0, column='Model Name', value='SVC')

## Model 5 - Random Forest

ml_rf=RandomForestClassifier(random_state=14,class_weight = cw,max_depth=100,max_featu
ml_rf.fit(X_train, y_train)
ml_rf_metrics = metric_utility(ml_rf,X_train, y_train,X_test,y_test)
ml_rf_metrics.insert(loc=0, column='Model Name', value='RF')


## Model 6 - Xgboost

ml_xgb=xgboost.XGBClassifier(objective='binary:logistic',random_state=14,max_depth=30,
ml_xgb.fit(sampled_X, sampled_y)
ml_xgb_metrics = metric_utility(ml_xgb,X_train, y_train,X_test,y_test)
ml_xgb_metrics.insert(loc=0, column='Model Name', value='XGB')

## Model 7 - NN Base

def create_nn():
  model = Sequential()
  model.add(Dense(32, input_dim=57, activation='relu'))
  model.add(Dense(16, activation='relu'))
  model.add(Dense(1, activation='sigmoid'))
  model.compile(loss='binary_crossentropy', optimizer='adam', metrics=['binary_accurac
  return model
dl_cfr = KerasClassifier(build_fn=create_nn, epochs=100, batch_size=256, verbose=0)
dl_cfr.fit(sampled_X, sampled_y)
dl_cfr_metrics = metric_utility(dl_cfr,X_train, y_train,X_test,y_test)
dl_cfr_metrics.insert(loc=0, column='Model Name', value='NN - Base')

## Model 8 - NN CW

def create_nn():
  model = Sequential()
  model.add(Dense(32, input_dim=57, activation='relu'))
  model.add(Dense(16, activation='relu'))
  model.add(Dense(1, activation='sigmoid'))
  model.compile(loss='binary_crossentropy', optimizer='adam', metrics=['binary_accurac
  return model
dl_cfr_cw = KerasClassifier(build_fn=create_nn, epochs=100, batch_size=1028, verbose=(
dl_cfr_cw.fit(X_train, y_train,class_weight = cw)
dl_cfr_cw_metrics = metric_utility(dl_cfr_cw,X_train, y_train,X_test,y_test)
dl_cfr_cw_metrics.insert(loc=0, column='Model Name', value='NN - CW')

## Model 9 - NN Regularization

def create_nn():
  model = Sequential()
  model.add(Dense(32, input_dim=57,kernel_regularizer=l1_l2(l1=0.01, l2=0.01), bias_re
  model.add(Dropout(0.2))
  model.add(Dense(16,kernel_regularizer=l1_l2(l1=0.01, l2=0.01), bias_regularizer=l1_l
  model.add(Dropout(0.2))
  model.add(Dense(1, activation='sigmoid'))
  model.compile(loss='binary_crossentropy', optimizer='adam', metrics=['binary_accurac
  return model
dl_cfr_reg = KerasClassifier(build_fn=create_nn, epochs=100, batch_size=1028, verbose=
dl_cfr_reg.fit(X_train, y_train,class_weight = cw)
dl_cfr_reg_metrics = metric_utility(dl_cfr_reg,X_train, y_train,X_test,y_test)
dl_cfr_reg_metrics.insert(loc=0, column='Model Name', value='NN - Reg')

Final_Metrics = pd.concat([ml_lr_base_metrics,ml_lr_metrics,ml_knn_metrics,ml_svc_metr
```

In [98]:
```python
Final_Metrics.head(10)
```

Out[98]:

	Model Name	Train_AUC	Test_AUC	Test_Accuracy	Test_F1_score	Test_Precision	Test_Recall
0	LR-BASE	0.913622	0.664138	0.907005	0.452594	0.627792	0.353846
0	LR-OS	0.913848	0.830584	0.851238	0.540160	0.406648	0.804196
0	KNN	0.914532	0.729244	0.857772	0.463303	0.392614	0.565035
0	SVC	0.914074	0.724203	0.887099	0.498312	0.481723	0.516084
0	RF	0.913645	0.842996	0.870081	0.574838	0.445988	0.808392
0	XGB	0.913960	0.688495	0.908828	0.492386	0.623126	0.406993
0	NN - Base	0.914307	0.763936	0.865978	0.506711	0.422181	0.633566
0	NN - CW	0.914116	0.843915	0.824647	0.518364	0.369423	0.868531
0	NN - Reg	0.913042	0.834893	0.818417	0.505994	0.359155	0.855944

Experimentation Summary

Given the problem statement of subscription campaign, Type I Error(False Positives) might be more acceptable than Type II error, since the campaign might benifit from wider net(assuming the reasonable campaign cost). Hence I would prioritize the models having high recall with a acceptible trade-off on precision.

From the above data, Logistic Regression(oversampled), Random Forest(HP Tuned) and NN(with Classweight) are suitable for the given problem statement and are used for Final prediction of this exercise.

End